ROVING EYE CAMERA MICROWAVE LINK ACTION REPLAYS

OUTSIDE BROADCAST

A CUP FINAL, A ROYAL wedding, news in the making – all are major events covered live on television by outside broadcasts.

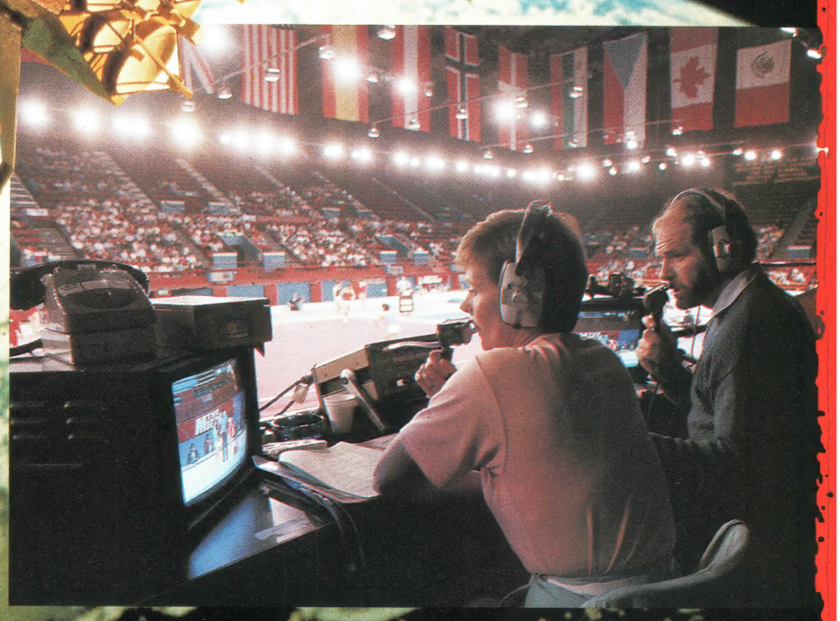
At the heart of a sports outside broadcast is the scanner, or MCR (mobile control room) – a vehicle as large as a luxury coach that houses the production team and its equipment. In the scanner's control room, in front of a bank of monitors, sit the director, production assistant, vision mixer and technical supervisor. These monitors show pictures of the event coming in from various cameras set up in strategic positions.

Picture quality

A second compartment inside the scanner houses the sound engineer with an assistant. Finally, in a third section are the engineers in charge of picture quality and the operators responsible for action replays.

Seth Shostak/Sc... Photo Library Thames TV

***Communications satellites**, located about 35,000 km above the equator, relay major sporting events from outside broadcast units (below) across continents.*



Diffraction filters are scribed with minute and closely packed radial lines. These produce spears of colours from highlights that can be rotated for best effect.

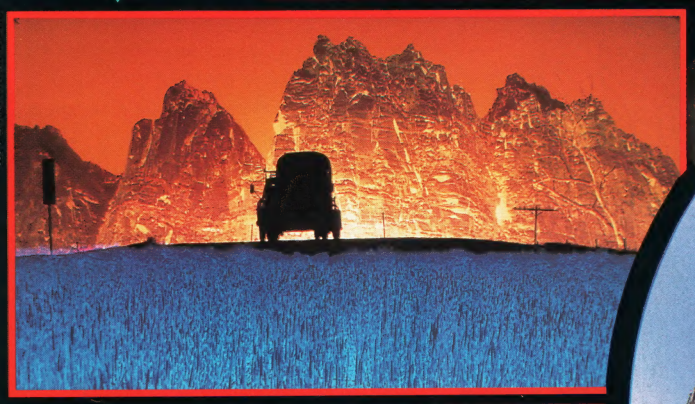
Coloured filters can produce bizarre results. Here orange and blue filters have been used to radically transform an early evening photograph of a field of wheat.

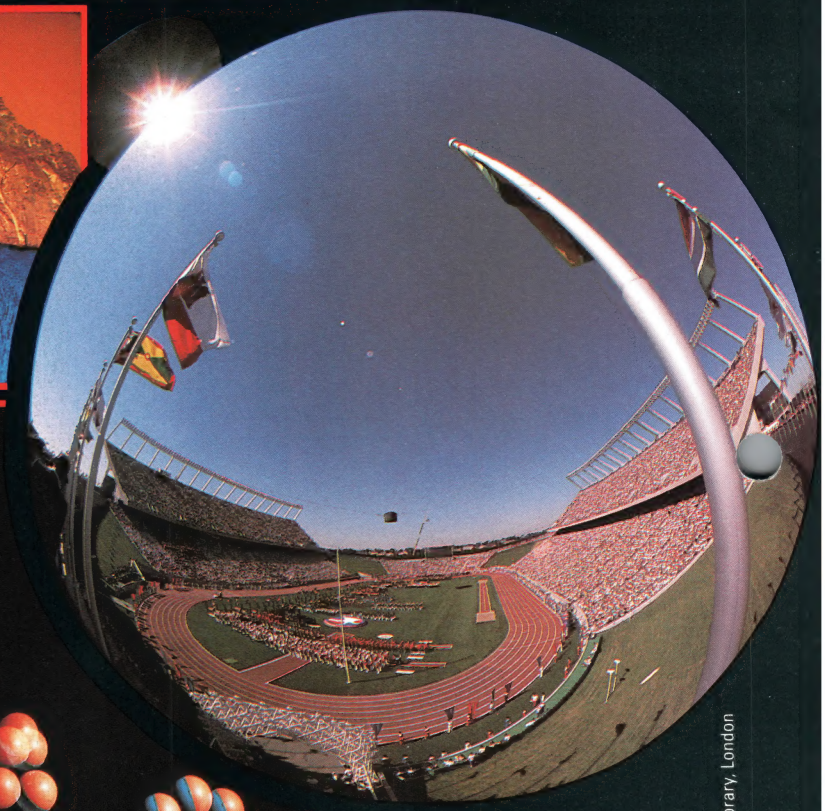
Martin Bond/Science Photo Library

Jonathan Watts/Science Photo Library

A high-speed photograph of the coronet formed when a drop of water falls into a liquid. Such a shot is captured with a 1/25,000 second flash, triggered by the sound of the water drop.

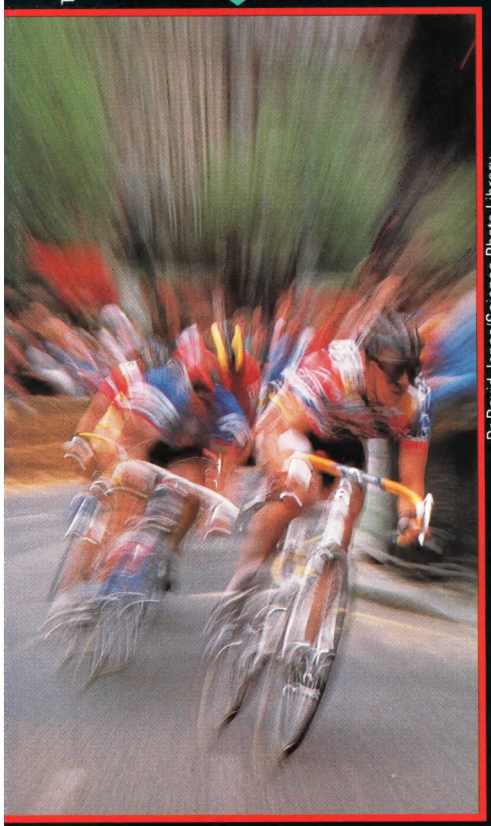
M Funk/Image Bank

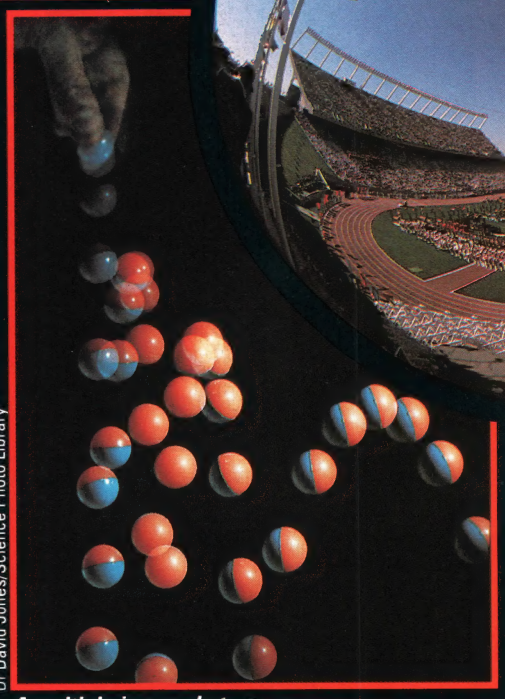




Tony Stone Photo Library, London

The 'explosion' effect – here of a cycling race – is used to create a feeling of speed. It is produced by zooming a variable focal length (zoom) lens, in this case out, during a slowish exposure of 1/30 to 1/60 second.





Dr David Jones/Science Photo Library

A multiple image shot of a bouncing ball. In this technique the shutter is held open and a high-speed flash is fired repeatedly.

Trails of car lights, in Mexico City, are achieved by means of a time exposure – leaving the camera shutter open for several minutes.

Tony Stone Photo Library, London

Tony Stone Photo Library, London

A fish-eye view of an athletics stadium. Typically, this circular image type of fish-eye lens has a focal length of 6 mm, a maximum aperture of f/2.8 and a field of view of 220°. The result is great distortion.

Q AIR CASTORS Q 'VARI-LIGHTS' Q SOUND EQUALIZER

BACKSTAGE

SPECTACULAR SCENERY AND special effects are all part of the thrill of a modern stage show – thanks to advances in theatre lighting and sound technology.

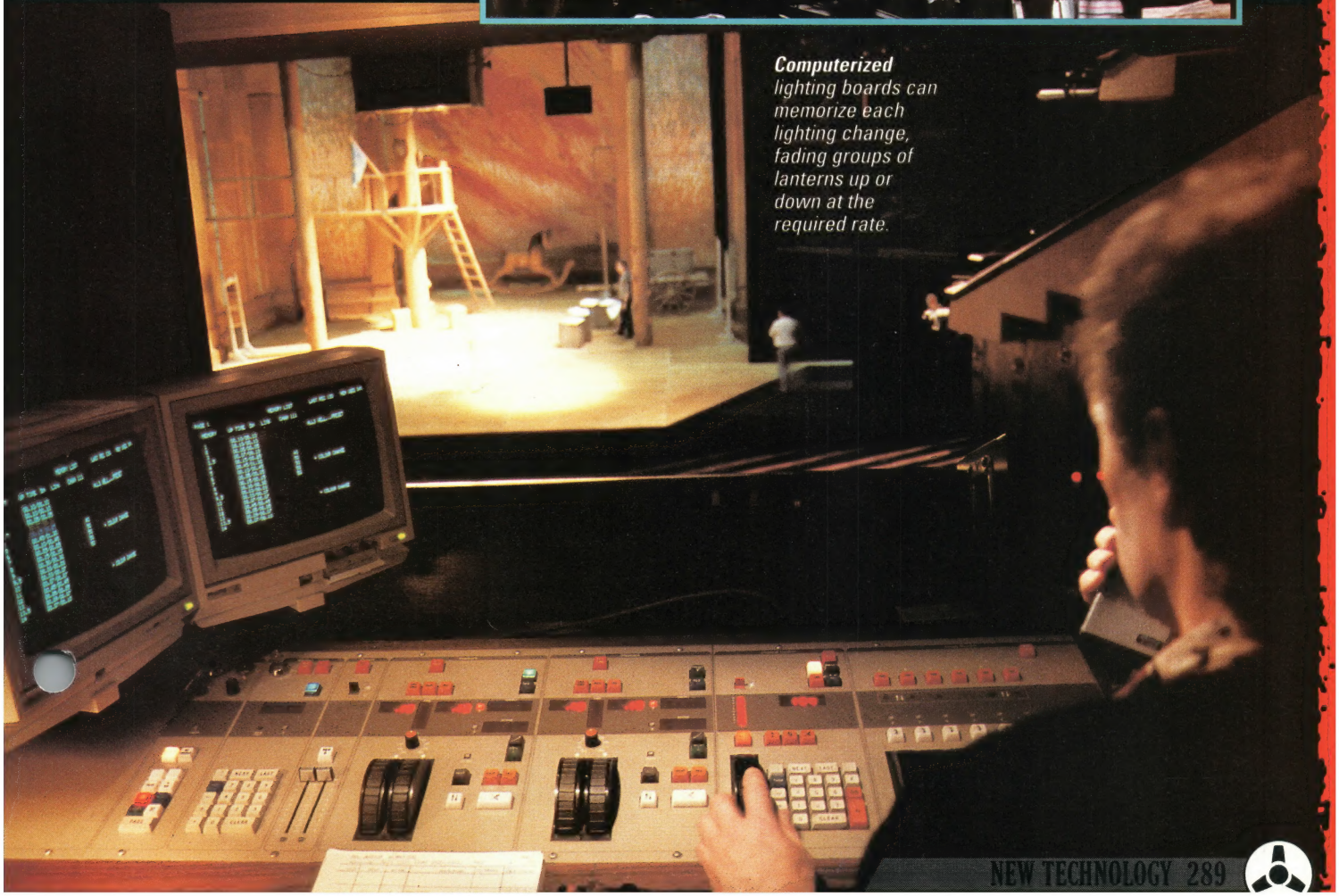
While many theatres still rely on brawny stage hands to move scenery, big modern shows use more advanced methods. There are essentially four ways of getting pieces of scenery on to and off the theatre stage:

- It can be pushed or pulled on from

Michael le Poer Trench

***A 10-metre high statue** of the Vietnamese leader Ho Chi Minh is hoisted on to the stage during the London-based production of the musical* Miss Saigon

Roy...Shakespeare Company/Barbican/Ray Duns



***Computerized** lighting boards can memorize each lighting change, fading groups of lanterns up or down at the required rate.*

the wings (the sides of the stage) or from the rear on 'trucks' (wheeled platforms)

- It can be 'flown in' on steel cables from the area above the stage (the fly-tower)
- Solid pieces of scenery can be placed on revolving sections of the stage to reveal different aspects of the set
- Scenery can be raised from below stage on movable sections.

Large, three-dimensional pieces of scenery are 'flown in' or 'trucked' on from the wings using electric winches and steel cables. A false floor is laid on the stage to keep the cables and tracks for the trucks completely hidden from the audience inside the theatre.

Revolving stage 'wagons', *like this one at the Lyttleton Theatre in London, are used for transporting heavy scenery on to the stage.*

Theatre Projects

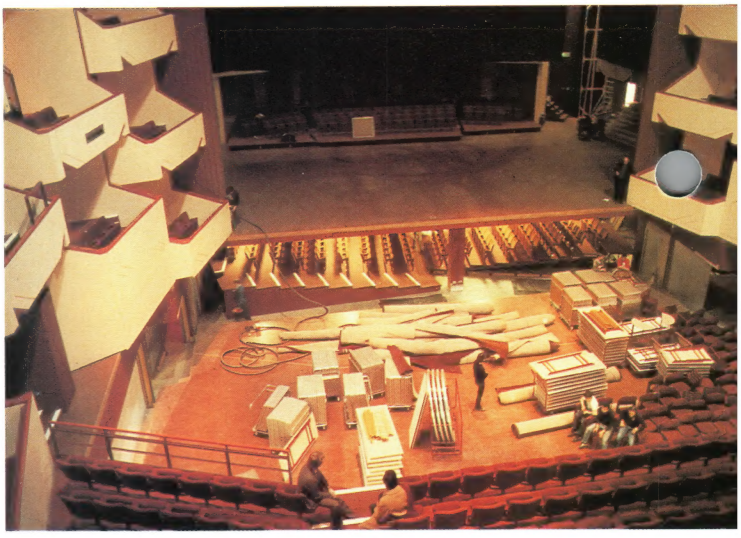
Raising and lowering large pieces of scenery through the stage is usually more complicated – often involving expensive excavation work underneath the theatre to accommodate bulky hydraulics.

The most advanced method of moving scenery on trucks is on so-called air castors. These allow large pieces to be moved on a cushion of air. When the pressure is turned off, the truck settles on the stage floor, anchored in place by its own weight.

Split-second timing

One of the greatest changes in production style has been the abandoning of the curtain. Scene changes now usually take place in full view of the audience at great speed. Split-second timing is required so that two separate pieces of scenery being lowered from the fly-tower and trucked in from the wings fit together precisely, while the lights make a corresponding change. To co-ordinate such movements a central computer is used to control the operation of all the winches. This ensures that no snagging or fouling takes place in the understage tracks or up in the fly-tower. The computer stores in its memory the exact distance that each cable should move at each cue or change in the show. At the touch of a button everything moves precisely into place – or should do.

The 1500-seater *Derngate Concert Hall in Northampton, UK, can be adapted for opera, ballet, drama, rock shows – even snooker matches. The seating is mounted on wagons that can be moved on air castors and stored under the stage. The walls of the theatre can be moved and re-settled in different positions, so changing the shape of the auditorium.*



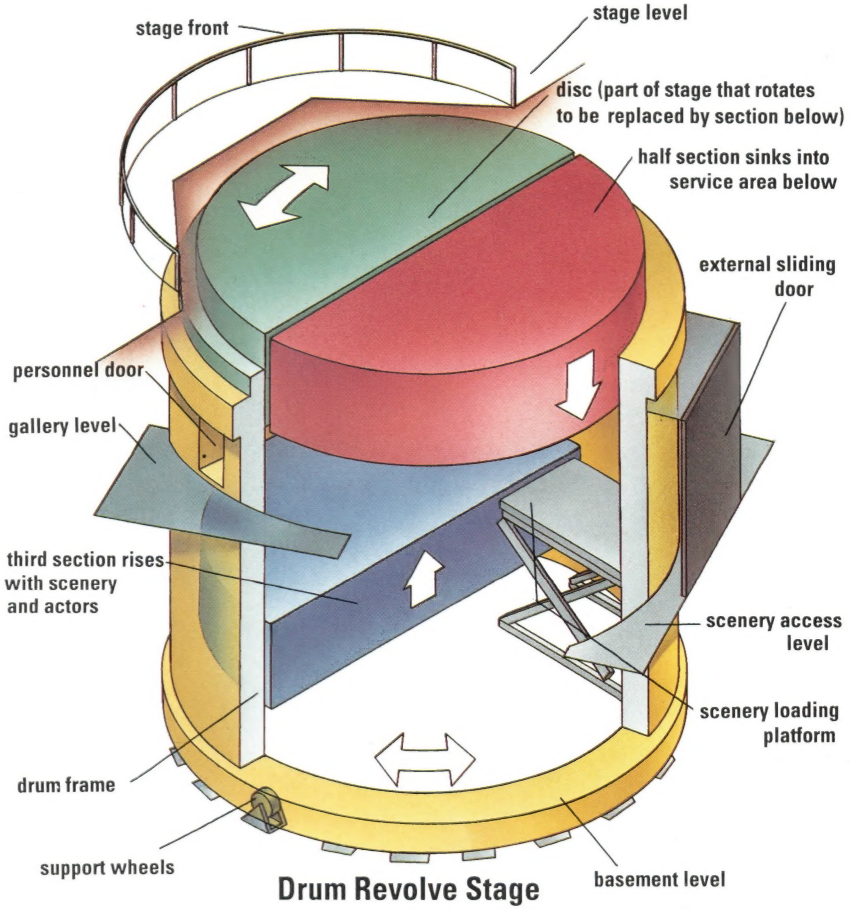
Theatre Projects

There are other problems, too. Steel cables, which support the pieces of scenery, expand and contract according to the temperature. These changes have to be monitored and alterations made on the distance counters to avoid collisions.

Computer memory

The most up-to-date lighting boards also depend on computer memory for each change in the lighting. But an experienced operator is still vital. The stage-manager, who is usually positioned at the side of the stage, watches the show, often on a video

This revolving stage *is built into the floor of the acting area. One half can be lowered to be replaced by a third section complete with new scenery.*



Drum Revolve Stage

Theatre Projects/Mark Franklin

screen. He or she calls out each cue over an intercom to the stage-crew, lighting and sound operators. Stage men will have every lighting cue marked in a script.

Lighting cues

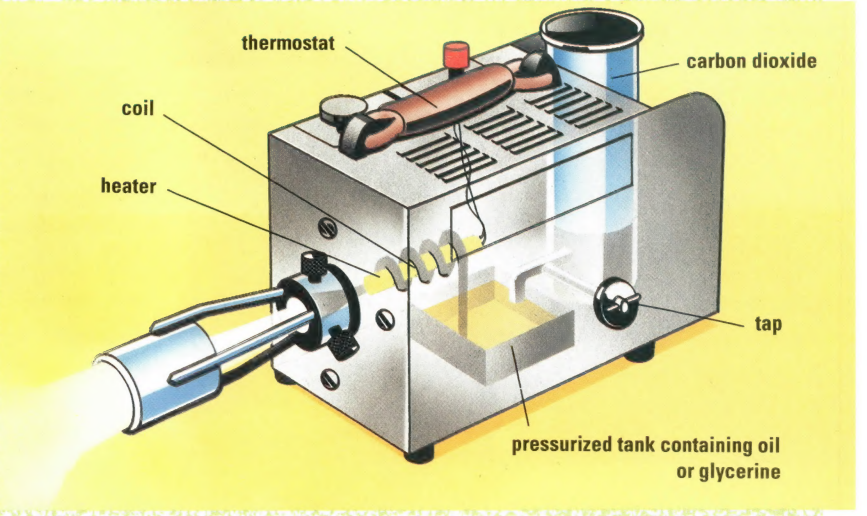
At that point the computer takes over. Each cue may require a series of light changes – fade-ups, fade-downs, colour changes and cross-fades – that would need an octopus to perform manually. But because the performance will vary from night to night, each cue is initiated manually. Otherwise, the computer might be pressing ahead, fading lights up or down, when the show has been brought to

Theatre Projects

Scenery hoist equipment *consists of a number of motorized suspension hooks. The hoists can operate together at a maximum speed of 2 metres per second, each carrying a maximum load of 200 kg. The controllers (right) sit in the fly-tower.*

Royal Shakespeare Company/Barbican/Ray Duns

SMOKE AND MIST ON THE STAGE



John Houghton

Stage smoke is produced with portable smoke machines or hand-held smoke guns. Oil, pressurized in its container, is forced around a heated, coiled tube where it turns into non-acrid, breathable smoke. For a rolling mist, dry ice (solid carbon dioxide with a temperature of -79° C) is usually used. When immersed in warm water, it produces a vapour that is heavier than air and billows across the stage floor. The warmer the water, the faster the vapour is made. Dry ice is super-cooled and must be handled with care, as it burns flesh.

operate are actually fairly simple in construction. The simplest kind of lantern is a flood, which is simply a lamp and a reflector in a box.

High-intensity lights

Par-cans are small, low-voltage high-intensity lanterns with the reflector and lens sealed within the same glass envelope as the filament. These can be connected in series to make up the standard voltage, and have also been adapted as the so-called Vari-lights that are a relatively new introduction to the theatre.

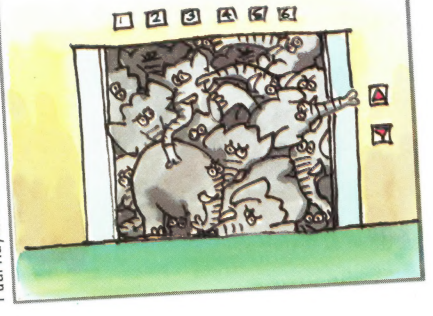
Unlike normal lanterns, which are fixed in place on a horizontal bar or vertical boom, Vari-lights can move on a track, re-focus and change colour according to the requirements

Royal Shakespeare Company/Barbican/Ray Duns

Just amazing!

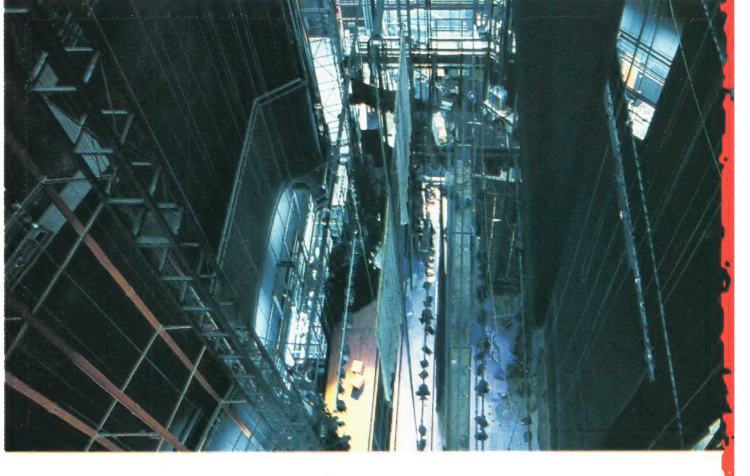
ELLY-VATED!

THE WORLD'S LARGEST THEATRE STAGE, IN NEVADA, USA, HAS 800 SPOTLIGHTS AND THREE ELEVATORS, EACH CAPABLE OF LIFTING 65 TONNES – OR 45 BABY ELEPHANTS!



Paul Raymonde

The scenery hoist operator's *view of the stage from the fly-tower. With modern mechanized systems, scenery of almost any size or shape can be 'flown in' at any angle. Each piece of scenery is counterbalanced by heavy loading weights.*

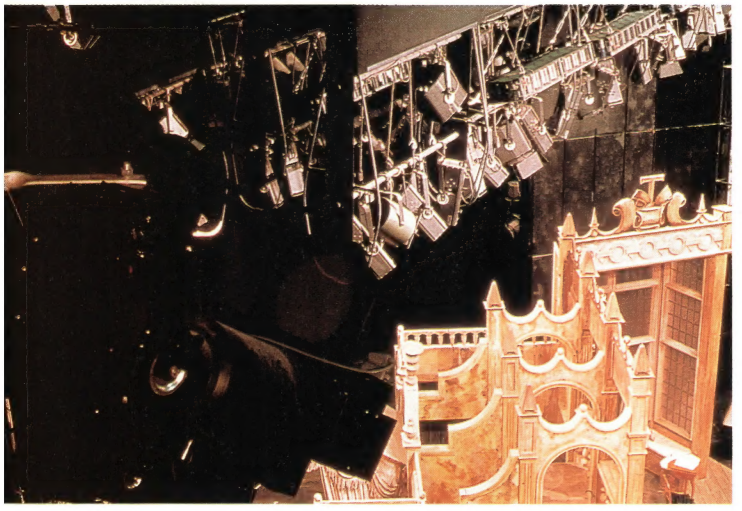


a standstill by a standing ovation!

The lighting operator sits at his board in a control box at the back of the auditorium, from where he can see what is going on. The lights – or lanterns – that he and his computer

of each new scene.

Many hundreds of these different types of lantern may be used to light a complicated scene. Most are hung above or at the side of the stage, but some can be seen shining from the



Theatre Projects

***Theatre lamps** – or lanterns – have to be used at varying levels of intensity and in different groups. 'Fresnel spots' are used for lighting large areas of the stage, while 'profile spots' give a sharply defined image of any object within their focal range.*

auditorium. From the back of the auditorium or sometimes from boxes at the side you will see powerful follow-spots being operated. Also known as 'limes' these are basically profile spots with a more sophisticated optical and mechanical design allowing illumination of the star or stars of the show, usually in a musical number.

Sound on screen

The other crucial element, especially in a musical, is the sound. The sound desk mixes the signals from the microphones on the stage and in the orchestra pit. The principal actors' or singers' voices are picked up by radio microphones. These are slightly larger than a matchstick and can be hidden in the actor's hair or clothing. They are connected to a small battery-powered transmitter, that is hidden in the performer's costume.

Nowadays the sound controller may be assisted by a high-speed analyser that gathers information from microphones placed in different parts of the auditorium and displays it on a screen.

***The sound desk** mixes the signals coming from microphones in the orchestra pit, from microphones at the front of the stage, which pick up actors' voices, and from radio microphones worn by the lead singers.*

Royal Shakespeare Company/Barbican/Ray Duns

The equalizer

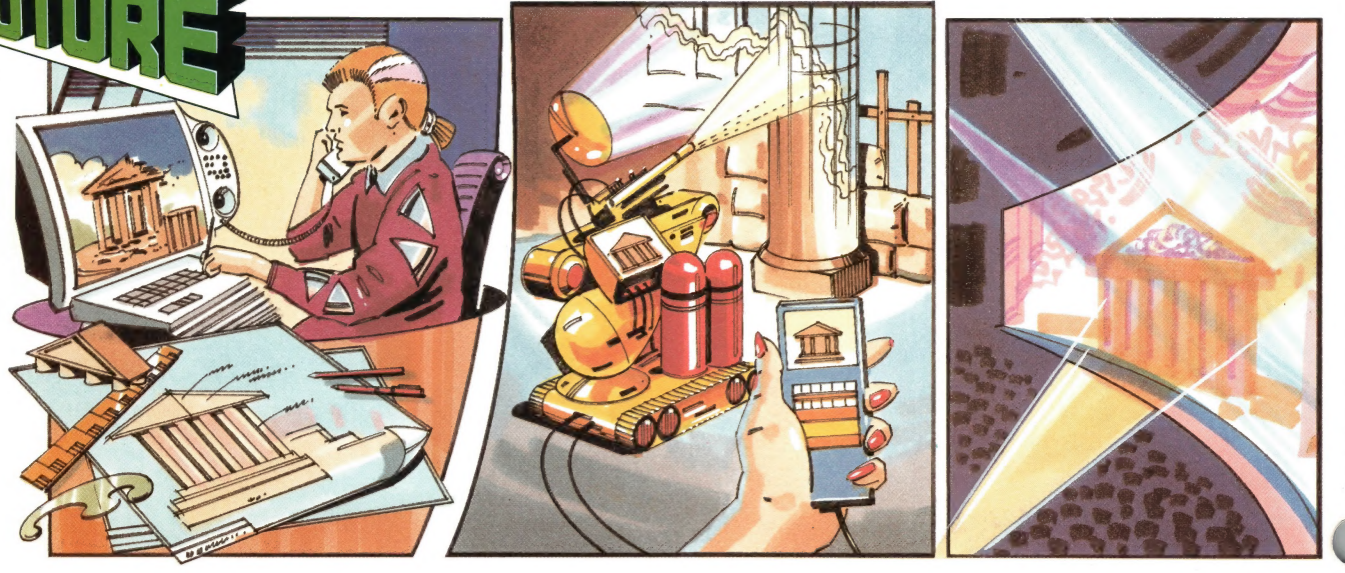
This sound equalization system is called a SIMTM and allows for the adjustment of sound quality by means of an equalizer during performance. The sound quality can vary according to the acoustic created by the size of audience and the air temperature on a given night.

The computer-assisted mixer feeds the signals to the equalizer, then to an amplifier and loudspeakers suspended above the stage and stacked at the sides. Programmable delay units within the system are controlled cue-by-cue by the mixing desk computer to ensure that the loudspeaker reinforcement coincides with the singer's voice, wherever he or she may be on the stage. This is essential in large theatres, where the sound from the loudspeakers can otherwise reach the audience out of sync with the singer.

The sound operator also has control of any sound effects, which are pre-recorded then fed into the mixer as needed from a tape recorder. This may include a facility to stop the tape at the end of each effect – a light-sensitive cell is activated by light shining through a strip of clear tape.

INTO THE FUTURE

ON-SCREEN STAGE SETS



Joe Lawrence

▲*When picture libraries become available on computerized data bases, set designers will be able to access any image world-wide via their domestic phone-line.*

▲*Three-dimensional sets will then be constructed direct from a computer design by a process using layers of liquid plastic which solidifies under UV light.*

▲*Holograms beamed on to the stage will replace conventional painted sets and make slide projection equipment a thing of the past.*

WEIGHTS AND MEASURES

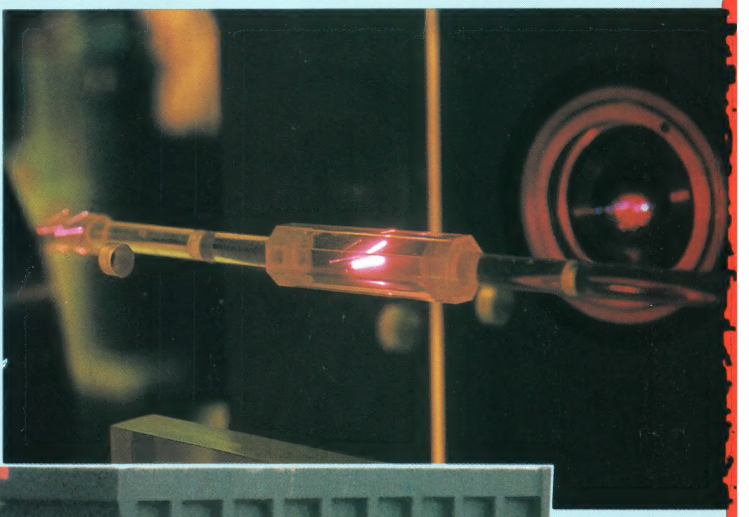
SINCE ANCIENT EGYPTIAN times, instruments for measuring lengths, weights and angles have remained much the same. Now though, with the advent of the microchip, a new generation of 'smart' tools has been developed.

For thousands of years the spirit level was a device that checked whether a surface is horizontal or vertical using a bubble floating in a coloured spirit in a small bottle, or vial. The level was placed on or against the surface to be checked. If the bubble came to rest between the two guide marks, the surface was flat and horizontal or vertical.

Checking angles

The curvature of the top edge of a vial is designed to give the instrument the required sensitivity – the distance the bubble travels for a given angle of tilt. Modern spirit levels are accurate to better than one twentieth of a degree. Some have battery-powered lamps built in to light up the vial, while the microchip versions are able to check a variety of angles.

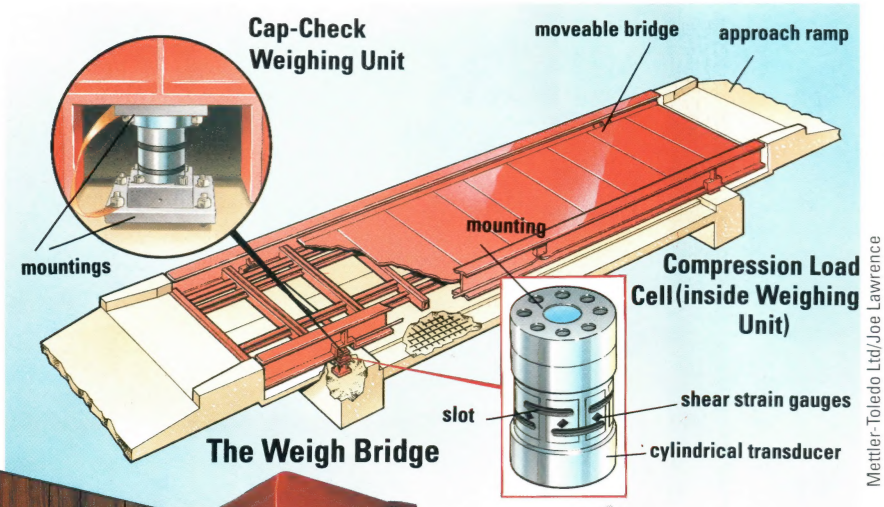
Measuring tape is often made of steel, protected by coatings of clear plastic. It is curved to make it more rigid so that it will support itself when a length is unwound from its reel. Alternatively, it may be made of fibreglass threads embedded in plastic. In Europe, good-quality tapes carry a mark showing that they conform to a European Community accuracy



Mettler-Toledo Ltd

***A weigh bridge** is used to weigh large lorries and their loads. At the other end of the scale, a laser device (right) is used to measure the size, shape and number of tiny cells in a liquid sample. Calculations are made from the way laser light is scattered.*

Jerry Mason/Harwell Laboratory/SPL



Mettler-Toledo Ltd/Joe Lawrence

Mettler-Toledo Ltd

***Inside the cap-check unit**, the walls of the load cell's transducer has slots in it, so it deforms when weight is applied. Strain gauges measure the distortion. The readout is passed to the operator's hut (left).*

standard. A Class II tape, for example, is guaranteed to be accurate to within 1.1 mm in three metres.

'Digital rule'

Today even the ruler can have a microchip built in. The 'digital rule' extends telescopically from one metre to up to five metres. The length is shown on a digital display. The user can switch between metric and imperial units at the press of a button. Accuracy is guaranteed to plus or minus 1 mm, comparing well with conventional tape.

It is possible to measure distances without having to stretch out a tape measure. Surveyors now use an ultrasound distance estimator to measure rooms. This 'electronic tape measure' sends out a pulse of ultrasound – high-pitched sounds too shrill for the human ear to hear. The device picks up the echo from the far wall of the room and calculates the distance from the time it takes for the sound to make the round trip.

False readings

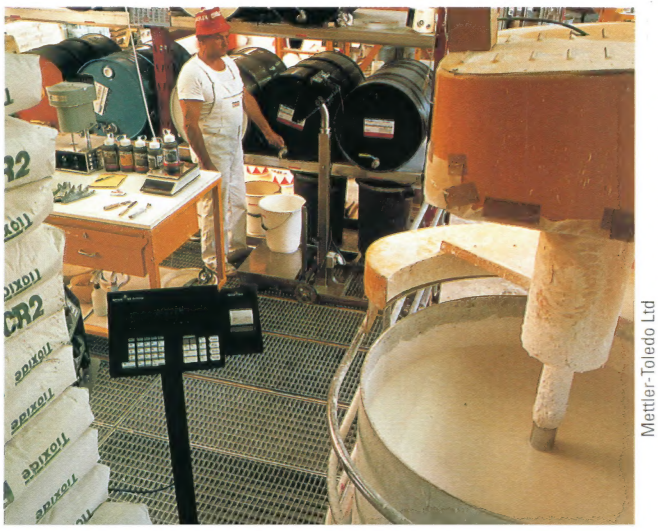
An ultrasound device can also be used, for example, to measure the distance across a busy street. However, accuracy is guaranteed to only 1 per cent – or 30 mm in three metres – making it much less accurate than a tape measure. There is also a danger of getting a false reading from a stray echo of something other than the object you are aiming at. This can be avoided by using a slightly more sophisticated ultrasound device which has a remote 'transponder'.

A transponder is a device that detects the ultrasound signal and sends back its own signal on a different frequency. It is placed against the object to which you are trying to measure the distance. The ulltrasound device can then tell the difference between the new sound sent back by the transponder and a stray echo from a different object that has the same frequency as the original pulse.

Electronic balance

Similarly, in the laboratory, old-fashioned scales have been replaced by the electronic balance. This has a pan that is attached to a coil of wire. When the object to be weighed is placed in the pan, the pan goes down. An electric current is sent through the coil, turning it into an electromagnet. A permanent magnet inside the device repels the electromagnet, resisting the pan's downward movement. The heavier the object, the greater the current that must flow to bring the pan back to its original position. The current is measured and converted into a weight reading. A laboratory balance can be accurate to a tenth of a milligram and can normally weigh up to 250 gm.

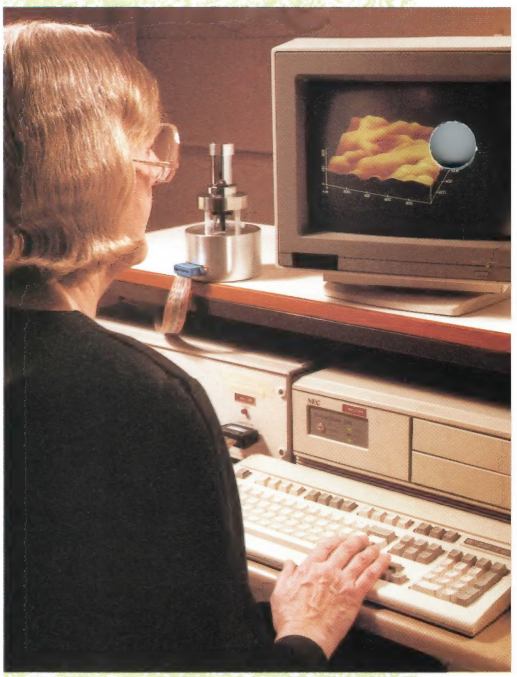
More rugged weighing machines are used in shops, company dispatch rooms, food-packing rooms and on the factory floor. These machines



Mettler-Toledo Ltd

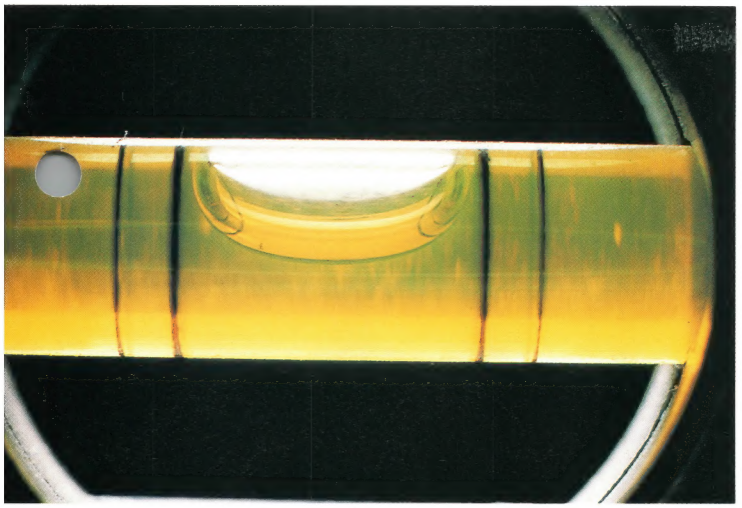
***Accurate weighing** is vital when mixing paint commercially. Each batch must be exactly the same shade as the last. Electronic scales are used to weigh the neutral-coloured paint base before the pigment is added.*

MEASURING ATOMS



The scanning tunnel microscope is not really a microscope at all, but a measuring device – a profiler that can measure details on the surface of a semiconductor down to one millionth of a millimetre across. The tip of a very fine wire is moved very close to the surface of the sample to be studied and electrons 'tunnel' between them. By moving the wire up and down, keeping the 'tunnelling current' constant, fine details of the surface can be resolved. The scanning tunnelling microscope can pick out individual oxygen atoms absorbed on the semiconductor's surface and pictures of such fine details can be built up.

Crown Copyright-National Physical Laboratory



In a spirit level, *when the bubble falls between the two lines, the surface is flat and level. That is how they have worked for thousands of years. Modern microchip versions tell the user how far out of true the surface is.*

A Assid/ZEFA

contain a 'load cell' – an aluminium or steel component that is bent or compressed when a load is placed on the scale. A 'strain gauge' attached to it generates an electric current – its size depends on how much it is compressed or bent. The current is then fed to an electronic scale, which instantly tells the user the total weight in either imperial or metric units at the press of a switch.

Mitutoyo UK Ltd

Dispatching

Sophisticated weighing machines will also show how many items there are on the pan and the cost of dispatching them by road, rail, courier or mail so the user can 'shop around' for the cheapest service at the touch of a button. The cost information is kept up to date by plugging in a new memory card whenever rates change.

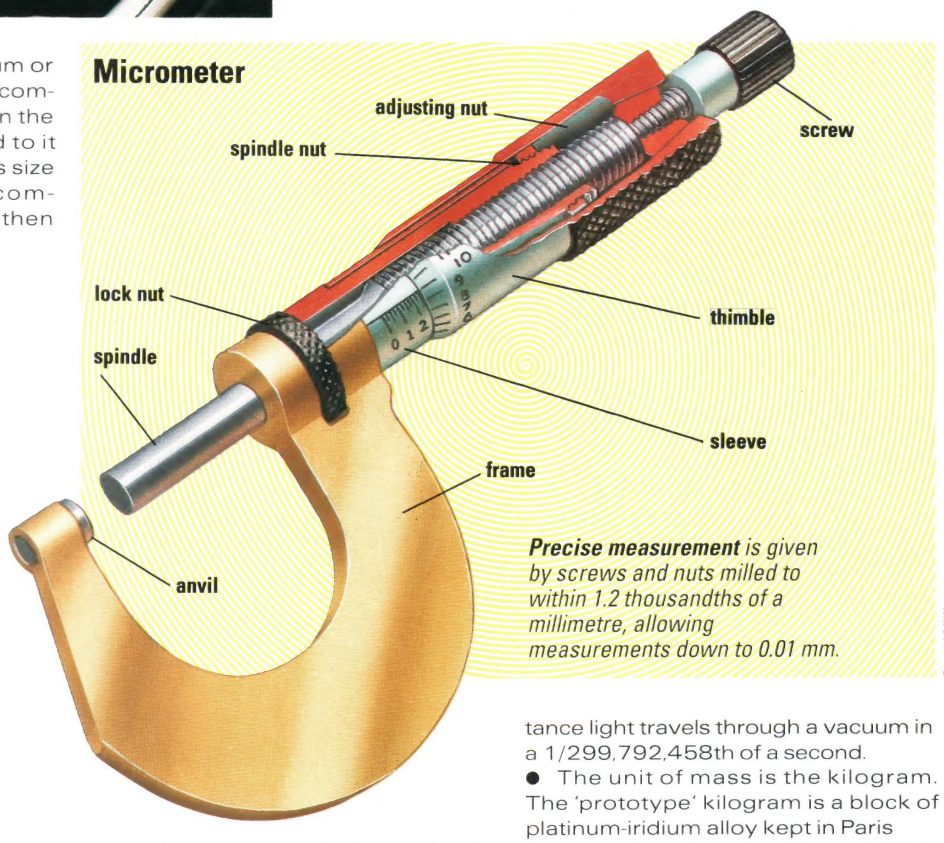
Vehicles such as lorries or railway locomotives can be weighed by being driven on to a weigh bridge or platform that is mounted on several load cells. In factories, scales can be hung from cranes or attached to the forks of a lift truck. They can be read from a distance by an operator using a hand-held infra-red control unit.

Electronic calipers *can measure widths down to 0.02 mm and the output can be fed direct to a recording unit. Some are even solar powered.*

'Base' units

All modern scientific units are defined in the *Système International*. There are seven SI 'base' units from which the other units can be worked out.

- The unit of length is the metre. It was first defined as one ten-millionth of the distance from the North Pole to the equator along a line through Paris. Then it was defined as the distance between two marks on a metal bar kept in a laboratory in Paris at constant temperature and atmospheric pressure. Now it is defined as the distance light travels through a vacuum in a 1/299,792,458th of a second.
- The unit of mass is the kilogram. The 'prototype' kilogram is a block of platinum-iridium alloy kept in Paris
- The unit of time is the second. This



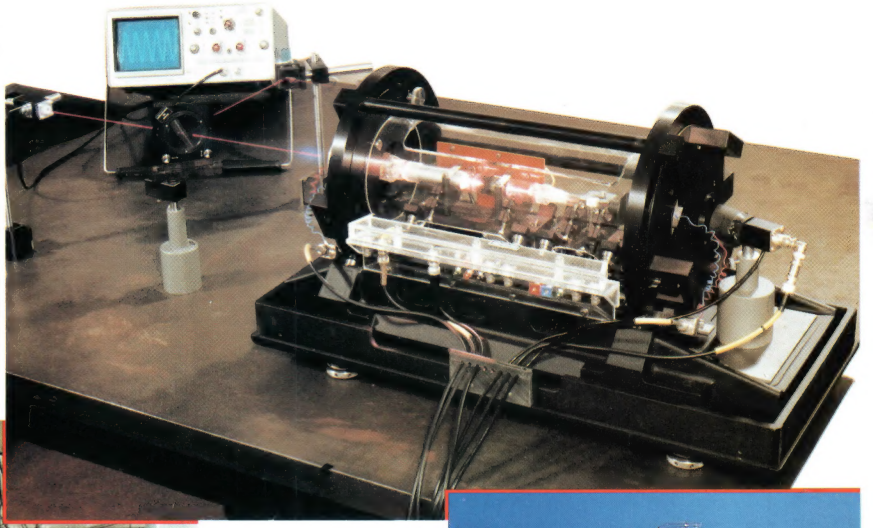
Precise measurement *is given by screws and nuts milled to within 1.2 thousandths of a millimetre, allowing measurements down to 0.01 mm.*

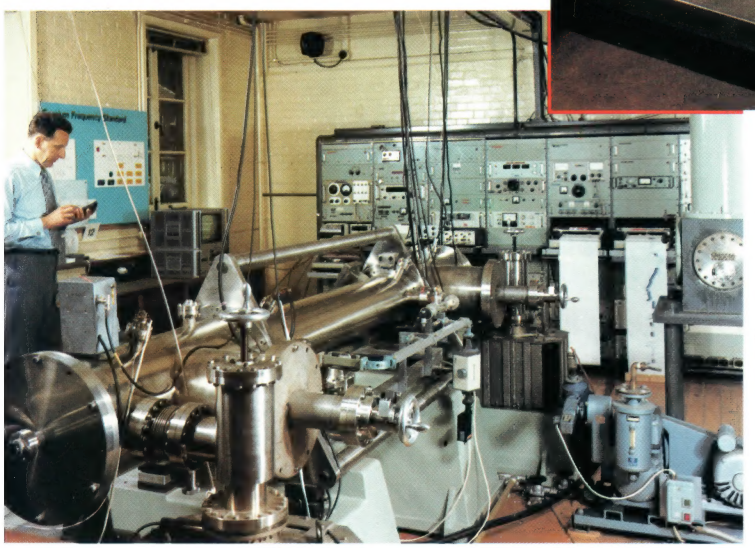
Paul Williams

Paul Raymonde

was defined as 1/86,400th of the time taken by the Earth to rotate once, but the Earth's rotation time was found to vary by as much as a thousandth of a second throughout the year, so the second is now defined as 9,192,631,770 vibrations of a certain radiation given out by caesium-133

- The unit of electric current is the ampère, or amp. This is defined by the electromagnetic force it generates
- The unit of temperature is the kelvin. When water is at its 'triple point' – the temperature and pressure at which ice, liquid water and water vapour can all exist, which is practically the same as its freezing point – it is defined to be at a temperature of 273.16 kelvin. Zero kelvin is 'absolute zero' – the lowest temperature theoretically possible. 1°C is the same as 1 kelvin, but the Celsius (centigrade) scale starts from the triple point of water, which is 0°C
- The unit of luminous intensity – the intensity of light – is the candela. It is based on the amount of light given off per second by melting platinum
- The unit of the amount of any substance is the mole. This refers to the number of 'elementary entities' – atoms or molecules. There is one mole present if the number of entities equals the number of atoms in precisely 12 gm of carbon-12. This number is approximately 602,300 million million million.

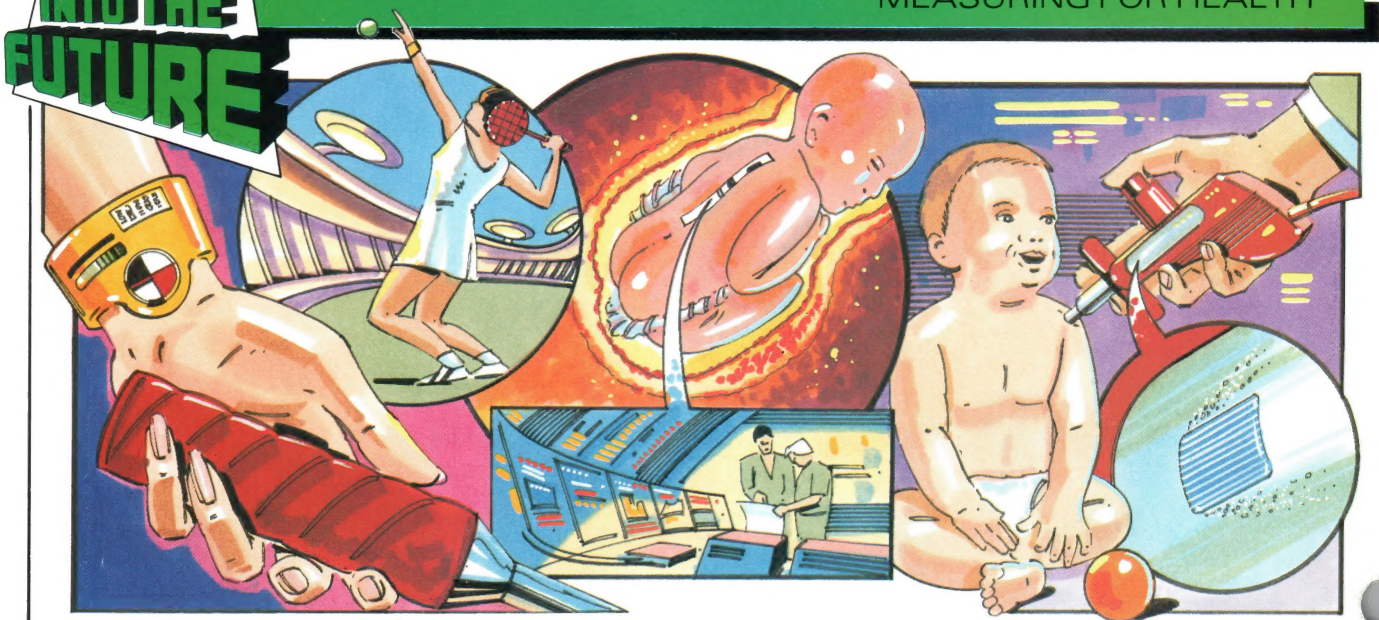




Time is defined *by a caesium clock. Atomic clocks are the most constant in the world, accurate to one thousandth of a second a year. The standard metre is fixed by laser light (above), while the prototype kilogram (right) is a block of platinum-iridium alloy kept in Paris.*

INTO THE FUTURE

MEASURING FOR HEALTH



▲ *The dieter of the future will have a constant weight readout from a device worn on the wrist. This will work out their weight from their movements.*

▲ *The development of a foetus will be checked by a highly sensitive device attached to the growing baby inside its mother's womb.*

▲ *Constant monitoring of the body functions of a growing child will also be possible so that health and development problems can be spotted early.*

Joe Lawrence

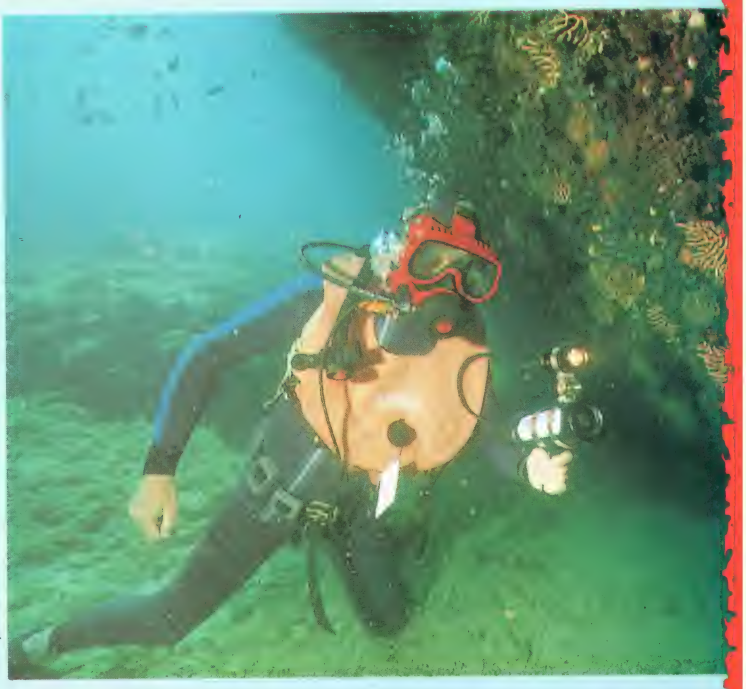
CAMCORDERS

VIDEO RECORDERS AND video cameras have brought about a revolution in home entertainment. Families can now enjoy pre-recorded films, record 'time-shift' television programmes that are broadcast at an inconvenient hour and even create their own home videos.

At the heart of the video revolution is the home video cassette recorder, or VCR. This works by running a 12.7 mm-wide plastic tape, coated with iron oxide, in front of a number of polished metal heads. The tape is contained within an oblong video cassette.

Recording heads transform the electronic signals coming from the television set into magnetic pulses that are stored in the iron oxide on the tape. The sound signal is laid down in a thin strip near the edge of the tape by an audio head. If a similar method were used to record picture information, it would take 100 km of tape just to hold a one-hour programme. So to avoid this problem, a rotating head drum containing two video heads records the picture signal in a series of long, diagonal tracks across the tape. When the tape is rewound and played back, the heads read the magnetic pattern

***This cameraman** is taking part in a French project designed to educate school children about marine life. His pictures are being recorded and simultaneously transmitted live to a study room from where the children can ask him questions via a telephone link.*

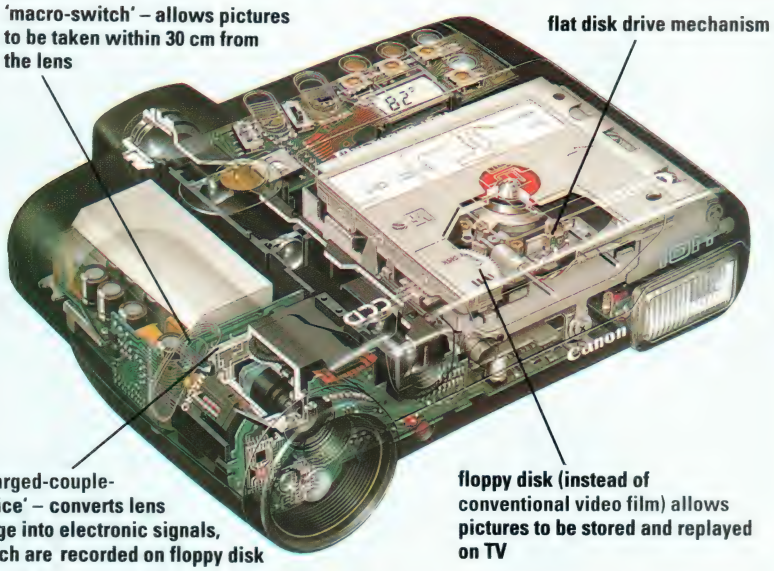


Mura/Jerrican

Ian Campbell

***Camcorders** can store picture sequences in their digital memory. These can later be edited and combined with other recorded pictures to make a home movie.*

The Canon Still Video Camera



Canon (UK) Ltd

Still video cameras *contain a tiny 'charge-coupled device'. This converts the image from the lens into electrical signals, which are recorded magnetically on a floppy disk. The pictures can be replayed on TV.*

and convert it back into an electronic signal to be sent to the television set.

The VCR is connected to a TV by a single cable. In this way, broadcast signals, picked up by the TV aerial, are passed on to the VCR even when the television is switched off. The VCR is equipped with its own receiver so that it can tune into any of the incoming channels. This allows, for instance, a programme on one channel to be viewed 'live', while the VCR records a programme being broadcast simultaneously on a different channel.

Advance recording

A timer enables the VCR to be set in advance to record a programme at any hour of the day or night. Most models now can be programmed to record a number of different programmes up to a week in advance.

Other features commonly found on today's VCRs include fast picture search, slow motion, freeze-frame and frame-by-frame advance, all of which control the speed at which the video is played. Finally, more and more VCRs are being equipped with facilities for making home movie-making easier.

Computer disks *are starting to replace film in still cameras. The disk can record up to 50 pictures, which means that the photographer can store thousands of shots in a space far smaller than is needed for conventional prints or transparencies.*

Gamma/Frank Spooner Pictures

Using a portable video camera it is now possible to record pictures and sound of everyday events directly on to video cassette tape. In some cases, the camera is connected to a separate VCR, either a standard model or a portable one powered by batteries. So-called camcorders, however, have the camera and recorder built into a single unit for easy handling.

Scanner

A boom microphone attached to the camera picks up the sound while a vidicon tube behind the camera lens scans the picture with an electron beam and converts it to an electrical signal. The main controls are the aperture for varying the amount of light entering the camera, the focus and the zoom.

Certain features on VCRs help the amateur to edit home-made videos. An automatic start-edit control, for example, gives invisible joins between picture frames when the tape is stopped and started. An audio dub control allows sound, such as a piece of music, to be superimposed on a previously-recorded video.

Tape counter

To do more sophisticated editing, two video recorders are needed with leads connecting their video out/in and audio out/in sockets. The original tape is viewed using one machine and the parts to be edited noted down with the help of the tape counter. Then the original tape is played again on VCR 1 while the new tape is recorded on VCR 2, using the start-edit control on VCR 2 to cut down on the distortion otherwise generated.

Among the latest developments in home video technology are VCRs that can record up to 15 hours of programmes on a single tape. This is done by running the tape at 0.78 cm per second, instead of the usual 2.34 cm per second, thus increasing the recording density. Video recorders will soon be available that can tape high-quality digital stereo sound along with the pictures.

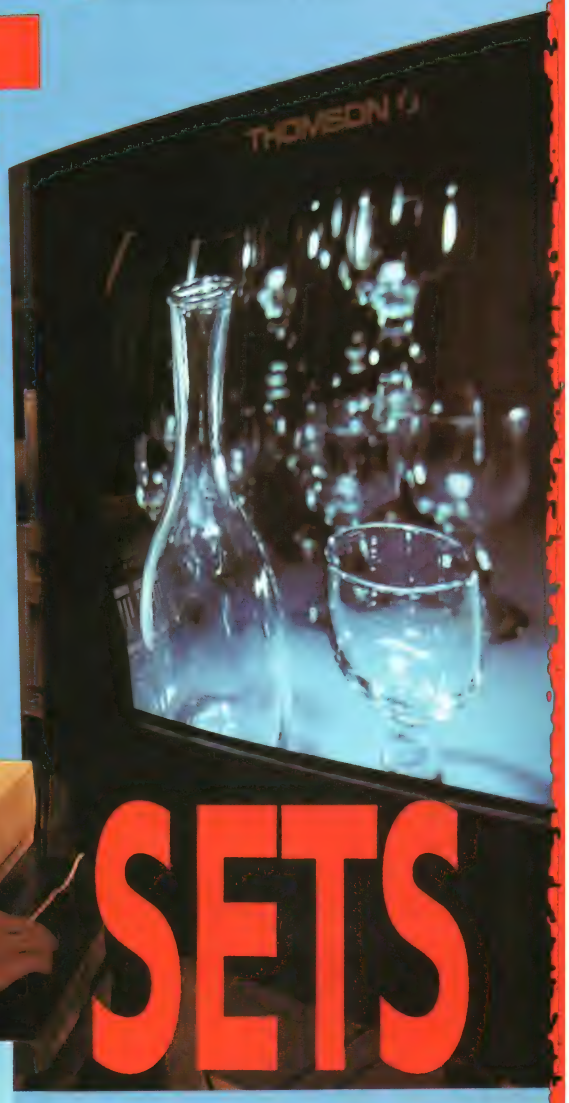
Paul Raymonde

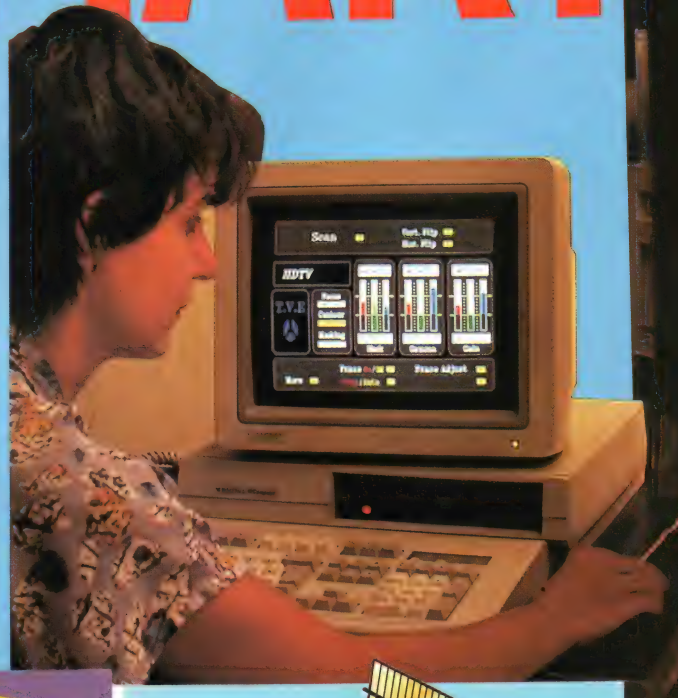
VCR CONTROL UNITS

Most VCRs now come with a hand-held remote-control unit. This sends signals to the VCR via an invisible infra-red beam. A person using the unit simply presses the appropriate button, say, to begin recording from a certain channel, and this command travels as a coded infra-red message. Inside the VCR, a sensor, tuned to the precise frequency of the remote control, picks up the signals and translates them into electronic pulses. A decoder chip recognizes the pulses and sends a signal to carry out the command.

HIGH DEFINITION TV ASPECT RATIOS BANDWIDTHS

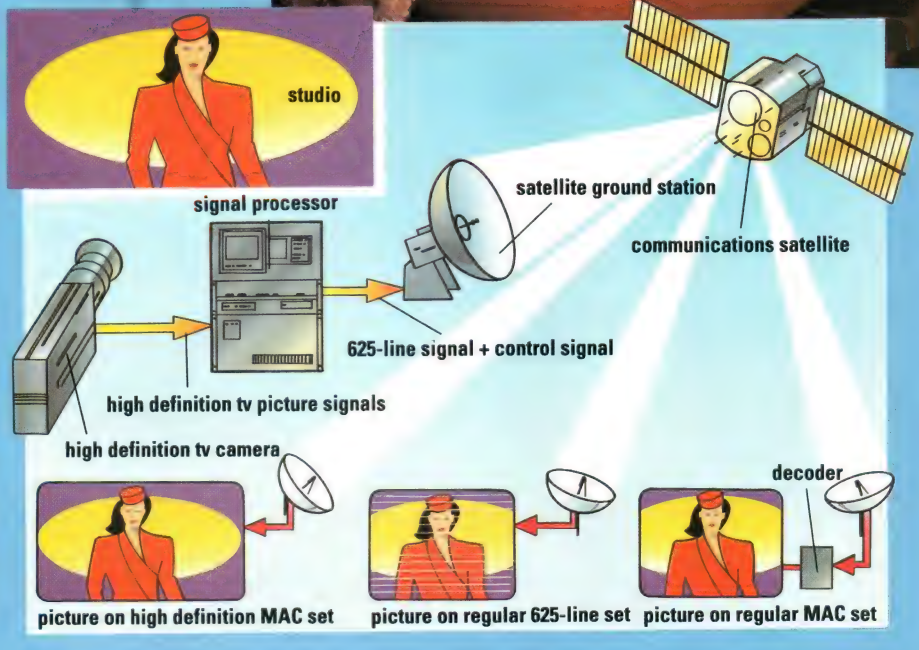
SMART SETS





***A technician** uses a personal computer to adjust the picture on an experimental French high definition television set. HDTV will not be broadcast in Europe until at least the year 2000.*

***Current MAC** high definition TV systems which are being developed will give true wide-screen HDTV, an enhanced picture on a regular MAC set and be available to viewers with normal TV sets.*



Joe Lawrence

FUTURE TELEVISION SETS will have clearer pictures and wider screens thanks to a new development called High Definition Television, or HDTV.

The number of horizontal lines on a TV screen limits the picture quality. Most of Europe, Africa, mainland Asia and Australia use the PAL standard – this has 625 lines. That number will be doubled in the next decade.

The United States and Japan use a different standard, known as NTSC, which has 525 lines. In Japan, more than 10 years of testing various types of HDTV has led the country to adopt a standard of 1,125 lines.

Wider pictures

Studies have also shown that most viewers would prefer screens with a higher aspect ratio – the ratio of screen width to height. So the aspect ratio of new televisions in Japan has been increased from 4:3 to 5:3, making them wider and better for showing films.

Philippe Plailly/Science Photo Library

European countries, meanwhile, are trying to agree on their own standard for HDTV. One system being considered would double the number of picture lines from 625 to 1,250 and increase the aspect ratio to 16:9.

Extra information

Improving the picture quality, however, means that the television signal has to be sent out at higher frequencies to carry the extra information. The problem is that the higher the frequencies, the wider the bandwidth or spread of frequencies. Present-day televisions use a bandwidth of 6 megahertz (6 million waves per second). Using the same technology, wide-screen televisions with over 1,000 lines would need a bandwidth of between 25 and 30 megahertz. This is impossibly high in today's overcrowded airwaves.

To reduce the bandwidth for HDTV, computers will be used to transform the high definition picture leaving the studio camera into digital code. The computer will map the pic-

High Definition TV *gives a noticably better picture than the current 625-line system (far right). With double the number of lines, HDTV no longer shows the scan lines the picture is made up from. So far broadcasts are restricted to Japan.*

Sony Broadcast & Communications

ture and log just the parts that are changing. The digitized picture will then be converted into two parts.

The experimental European HDTV system uses a conventional analogue 625-line image and one digital control signal that contains information about the picture content.

The control signal is transmitted in the same way as Teletext, that is in the unused picture lines that form a thin black border at the top and bottom of the screen. The HDTV set will use the control signal to process the accompanying analogue signal. This enables the bandwidth for transmitting HDTV signals to be cut from 25 megahertz to 12 megahertz, which can be handled by regular satellite transmission. In 1992 the Olympic Games were broadcast in parts of Europe on HDTV. However, in 1994 technical production difficulties emerged which would make domestic sets extremely expensive and the project was suspended.

Sony Broadcast & Communications

No great leap *of technology is required in the studio to produce High Definition Television. The problems come when the extra picture data has to be broadcast.*

American Success

An American project is being developed by a combined effort of AT&T, General Instrument, the Massachusetts Institute of Technology, Zenith Electronics and other companies. The research team undertook experimental broadcasts in North Carolina in 1994. It is hoped that improvements developed as a result of these tests can be swiftly implemented and a final package developed for tests by late 1995 or early 1996.

Rather more successful is PAL-Plus which enables wide-screen movies to be transmitted via existing networks. Several TV stations transmit movies via PAL-Plus. On ordinary TV sets the picture appears as a 'letter-box' with black bands above and below the picture, but on PAL-Plus receiving sets the picture is enlarged to fill the entire screen using coded instructions in the black bands.

Just amazing!

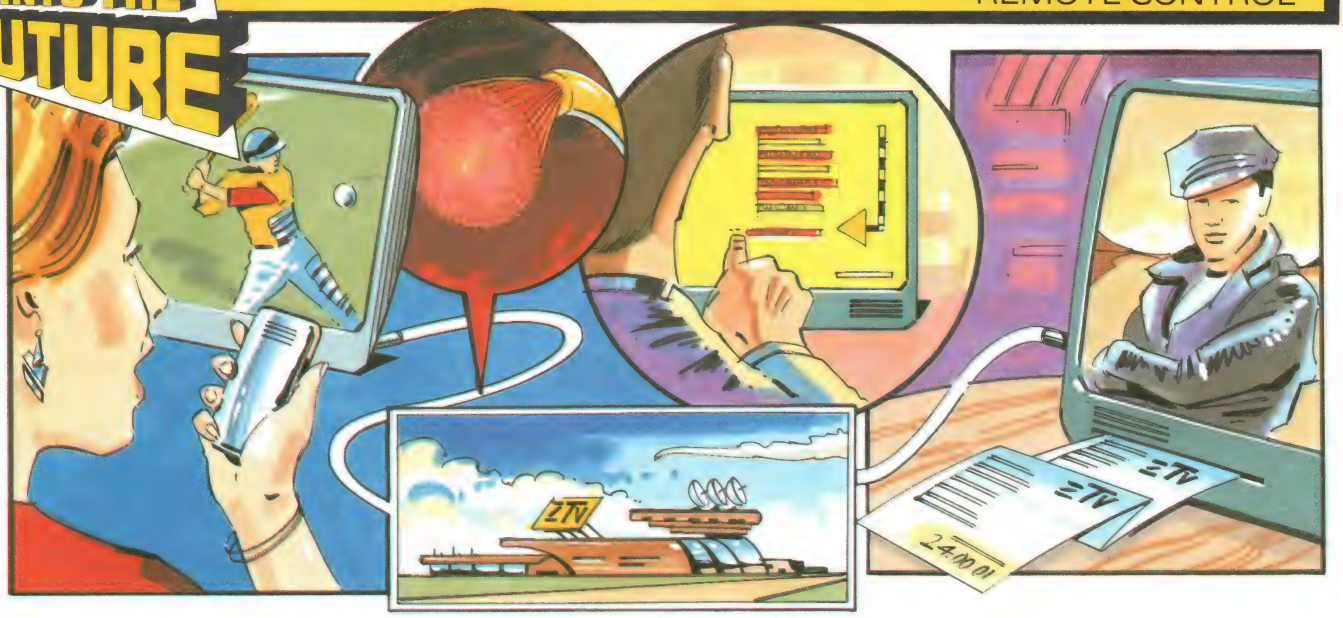
SOAP STARS

TV SIGNALS TRAVEL OUT INTO SPACE – SO ALIENS NEAR BARNARD'S STAR, 5.9 LIGHT YEARS AWAY, WILL BE WATCHING NEIGHBOURS SIX YEARS OUT OF DATE.

Paul Raymonde

INTO THE FUTURE

REMOTE CONTROL



▲ *A TV remote-control with no buttons. Ask to see a film or TV show. The request is sent by infrared link to the set, then via fibre-optic cable to the TV company.*

▲ *There your request is fed into a voice-recognition unit. On recognizing your request, the system may transmit a message back, asking for further details.*

▲ *The system retrieves the programme from a digital store and transmits it to your set. A record is kept, so you can be billed at the end of the month.*

Joe Lawrence

TORQUE CONTROL ANGLE DRILLS ALLIGATOR SAWS

HAND POWER

WITH ELECTRIC POWERED drills, saws and screwdrivers at their elbows, the modern carpenter, plumber and builder can work faster and their amateur counterparts can easily achieve craftsmanlike results.

Over the last few years, there has been quite a revolution in electric drills and other power tools. Old-fashioned tools had long trailing wires that were potentially dangerous – there was always a risk that they would be cut or damaged. Many new power tools have rechargeable batteries built in so that they can be used remote from any power source.

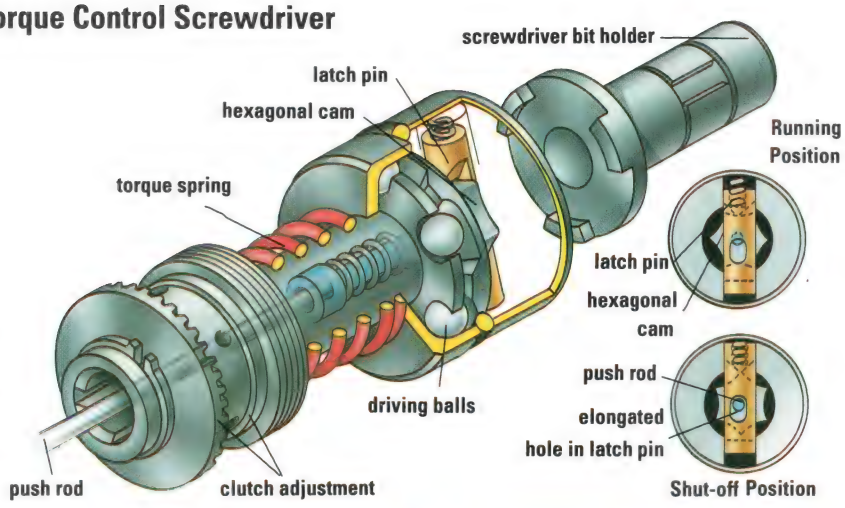
A drill operator can now key in information about the material to be worked upon. The drill will then select the right speed and power needed to

Atlas Copco Tools AB

Black & Decker

***Grinders**, powered by compressed air, are used to smooth down aircraft hulls. Modern hammer drills (right) have electronic controls that select the correct speed automatically. A memory facility ensures that the machine repeats the setting precisely for repetitive screwdriving or drilling jobs.*

Torque Control Screwdriver



Desoutter/Mark Franklin

***Some electric screwdrivers** have different clutch control settings. These allow the operator to vary the degree of torque (twisting power) according to the task in hand.*

Stihl

***An 'environment-friendly' chain-saw**. A catalyzer reduces the amount of noxious hydrocarbons in the exhaust gas by 80%, and the chain is lubricated by a synthetic oil that decomposes on the forest floor within three weeks.*

complete the job and will confirm the appropriate settings on a small liquid crystal display screen!

Most drills now boast 'hammer action' for drilling into masonry. The hammer action knocks the drill bit back and forth while it is turning, literally hammering the bit into the brick or stonework.

Electric drills are now reversible, so that the bit can easily be extracted if it is stuck. And if the drill also has 'torque control' this means it can also be used as a powered screwdriver. Torque control sets a limit on the amount of twisting force the drill will provide so that it will stop turning when the screw is driven fully home. Small purpose-built electric screwdrivers have become popular.

Tough tips

Most modern drill bits are tipped with super-hard tungsten carbide – as are the blades of power saws. This gives them a longer life before they blunt.

The new alligator-type of saw is taking over from small chain saws for domestic use. Instead of a chain being pulled around the edge of the blade by a petrol engine, the electrically powered alligator saw has two straight blades with serrated edges. The blades cut by moving back and forth in opposite directions.

Although these are set to take over some of the work of small circular saws, the circular saw still has the advantage that the blades can be set to a precise angle and depth.

Jig saws, which are used to cut precise patterns in flat surfaces, now incorporate scrolling – the blade alone can be turned without turning the whole saw. Modern jig saws also contain a blower system to blow dust away from the cutting line so that the operator can see what he is doing.

Vacuum cleaning

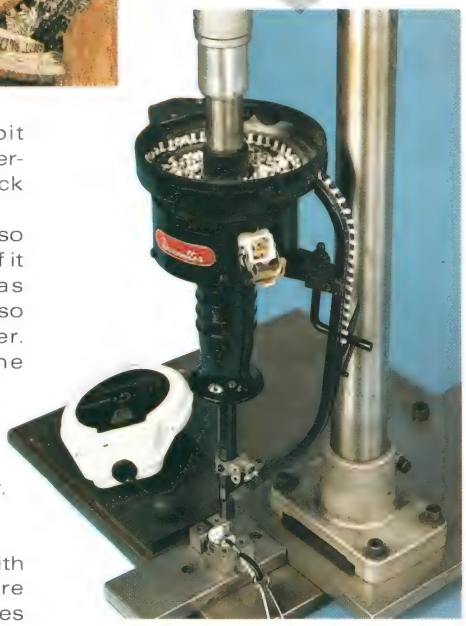
Dust is even more of a problem with sanders. But the latest sanders have a vacuum-cleaning system built to suck up the dust produced when working through holes in the base.

Another useful invention in the home DIY area is the steam wallpaper stripper. This works a bit like a steam iron. It forces jets of steam through the wallpaper to soften the paste underneath, allowing the paper to be peeled easily off the wall.

Electric power tools are rarely used in industry because of the risk of electrocution and sparks causing a fire. Pneumatic tools are much safer. These are connected to an air hose and powered by air at a pressure six times greater than normal atmospheric pressure.

In industry, precise tools are required for precise jobs. As well as straight drills, where the bit points directly out of the front, you will find angle drills where the drill bit is at right angles to the body of the drill so holes can be drilled in tight corners.

***An electric screwfeeder** – used in the manufacture of a wide range of products – feeds the screws automatically to the driving head, ready for fastening.*



Desoutter

Just amazing!

NUTS

THE WORLD'S LARGEST NUTS – 'PILGRIM NUTS' – WERE MADE FOR A LARGE FORGING PRESS. EACH IS 132 CM IN DIAMETER, WITH A THREAD OF 63.5 CM AND WEIGHS 4.7 TONNES!

Paul Raymonde

Q AIR TURBINE DRILLS Q ULTRASONIC SCALERS Q X-RAYS

DRILLS 'N' FILLS

ZEFA

PROCEDURES FOR FILLING AND extracting teeth have changed little in recent years, but sophisticated tools are making the dentist's life a lot easier.

One of the greatest advances in dentistry has been the development of the high-speed air turbine drill. The drill bit – or bur – is mounted in a chuck that sits on a tiny turbine. The handpiece is connected to an air hose and the compressed air flowing past the turbine spins the drill at 250,000 to 500,000 revolutions per minute.

Although the drill spins very fast and cuts through tooth enamel quickly, the power of the compressed air drive is very low – allowing the bit to halt rapidly if it hits an obstruction. The exhaust air also cools the tooth and water sprayed through the drill washes out the debris.

Amalgam

The final preparation of a cavity is done with hand tools. Small chisels with stainless steel or tungsten carbide tips are used to cut the margin of the cavity and excavators are used to scoop out the decayed dentine.

Dental amalgam is used for most fillings. This is a mixture of metals mostly silver with some tin, copper

***The latest electronic treatment unit** allows the dentist, with finger-touch control (below), to programme instruments, adjust the position of the patient and even refill the water tumbler.*

Siemens

Siemens

An environment-friendly *automatic separating system traps over 95% of amalgam and mercury spat into the cuspidor (sink) by patients having work done on fillings. A rotating ball cleans the internal system walls automatically.*

ANIMAL DENTISTRY

Extraction of an infected elephant tusk requires highly specialized tools and instruments – usually designed by animal dentists themselves. Such an operation may require four dental surgeons, and two vets to administer anaesthetic. The scaffolding shown is used to help the retraction of tusk sheath or cheek. Zoo animals often suffer dental decay as a result of eating the sweets and sticky buns thrown to them by visitors.

Peter Kertesz

and zinc added – softened by mercury. The mixing is done mechanically in a 'vibrator'. The soft paste produced is put into an amalgam carrier and forced into the cavity. A plugger compresses the amalgam and a carver shapes the surface. The finish is smoothed with a burnisher. The dentist has only a few minutes to smooth and shape before the amalgam becomes hard enough to bite on.

The operating light that hangs over the patient's chair usually incorporates a rigid quartz rod or flexible fibre optic light guide. This is used to 'cure' the light-sensitive white filling materials used in front teeth. The light output is filtered towards the blue end of the spectrum as most light-activated materials respond better to blue light.

Tartar blasters

Also suspended above the chair is an X-ray machine. This is mounted on an articulated arm and can be pointed at the patient's mouth in any direction. The X-ray film is held in a plastic 'bite wing' holder clenched between the patient's teeth. Once exposed, it must be developed. Some dental surgeries have facilities to do this themselves.

In up-to-date dental surgeries, hand scalers have given way to air or ultrasonic scalers. Air scalers are like small pneumatic drills that hammer tartar (a hard deposit, mainly of calcium phosphate) off teeth. Ultrasonic scalers have a tip that vibrates at a high frequency. Both types of scaler dislodge tartar with a minimum of effort on the part of the dentist and give the patient only a slight tickling sensation. The energy expended, though, is so high that the tip must be water cooled, which has the added advantage of flushing away the debris.

Siemens

Titanium instruments *can be given a very smooth surface that will harbour few germs. The scanning electron micrograph (below) shows diamond grit embedded in a metal drill bur.*

Manfred Kage/Science Photo Library

Just amazing!

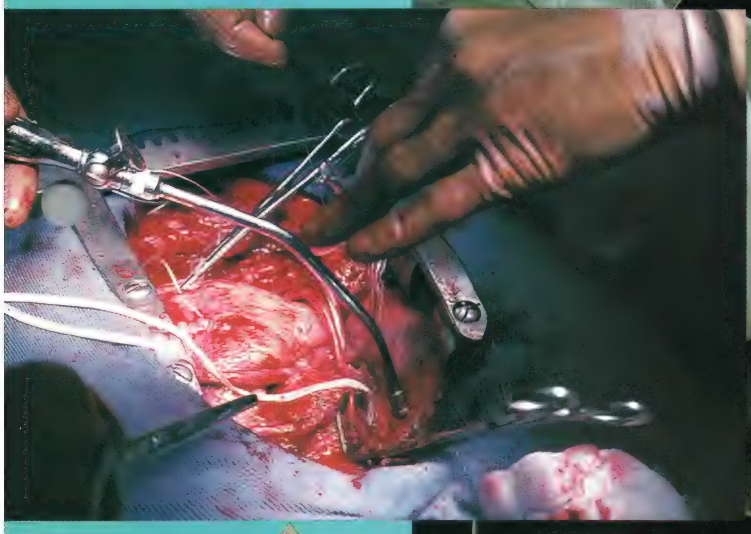
SEEING IS BELIEVING

TO PERSUADE PATIENTS TO CLEAN THEIR TEETH PROPERLY, SOME DENTISTS ENTERTAIN THEIR CAPTIVE AUDIENCES WITH BLOWN-UP PICTURES OF THE TARTAR SCRAPED OFF THEIR TEETH.

Paul Raymonde

- PERCUTANEOUS TOOLS
- NEEDLES AND BLADES
- SKIN GRAFTS

NEW SHARPS



***A retractor** holds open the edges of a wound during open-heart surgery. Forceps (tiny pincers) grasp blood vessels to stop bleeding temporarily.*

Tony Stone Photo Library, London

THE LATEST ADVANCES IN surgical procedures mean that surgeons are having to get used to a whole new generation of operating tools. These are smaller, lighter, more sophisticated and more expensive than ever before.

Some modern operations, such as sewing back a severed limb, are much more intricate and take much longer than traditional surgery and so surgeons need lighter instruments to work with to prevent fatigue. Many modern tools, made of the rare metal titanium, are less than half the weight of standard stainless steel tools. Titanium is also more brittle than stainless steel, allowing it to be machined to a very fine point. This is vital for operations where nerves and tiny blood vessels are sewn together.

Microsurgery

Surgery on this scale – microsurgery – is performed under a microscope at 30 times magnification. Around even the smallest blood vessel there has to be at least eight stitches to make the joint blood-tight. The nylon thread used is no greater in breadth than a human hair and the minute needle has to be held by a titanium needle-holder – no other material can be worked to a fine enough point. Titanium tools, though, cost several times their stainless steel equivalent.

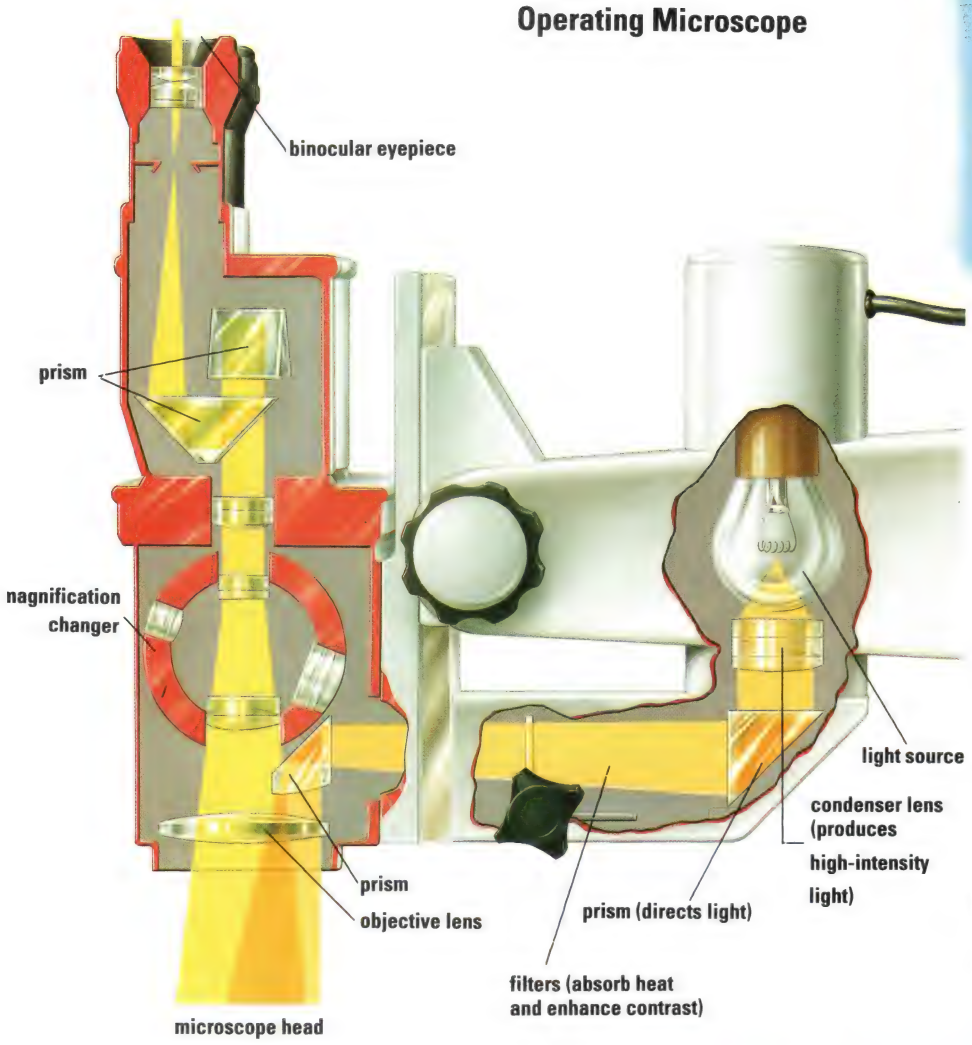
***Sterilized surgical instruments** are laid out in advance of an operation to save time. Sixty pairs of forceps may be used in a single operation.*

Tony Stone Photo Library, London

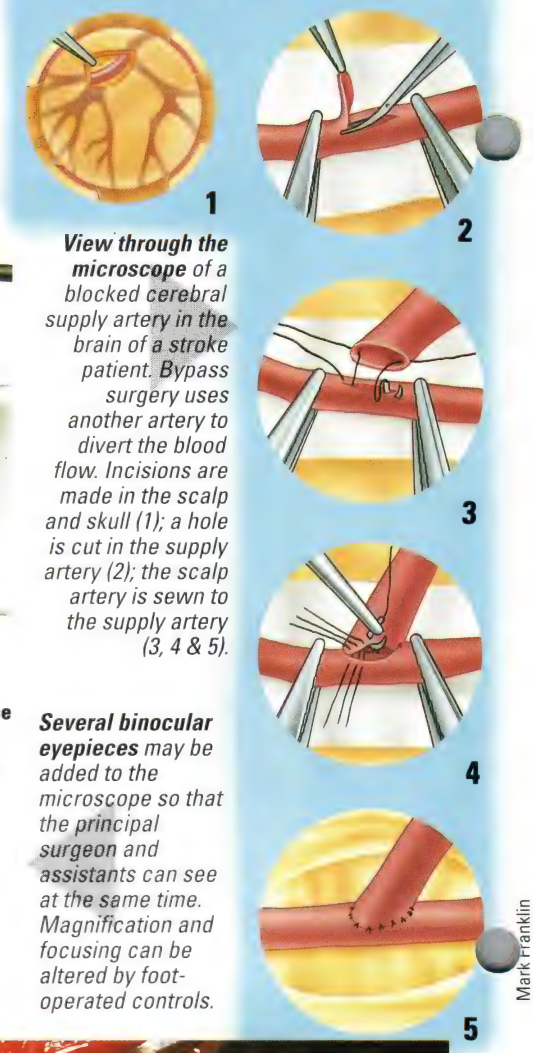
New metals

Tungsten carbide – the material used in modern drill bits – is used to line the insides of the jaws of forceps to improve grip and the cutting edges of scissors to improve wear. But, again, tungsten carbide is very expensive

Operating Microscope



Artery Bypass



View through the microscope *of a blocked cerebral supply artery in the brain of a stroke patient. Bypass surgery uses another artery to divert the blood flow. Incisions are made in the scalp and skull (1); a hole is cut in the supply artery (2); the scalp artery is sewn to the supply artery (3, 4 & 5).*

Several binocular eyepieces *may be added to the microscope so that the principal surgeon and assistants can see at the same time. Magnification and focusing can be altered by foot-operated controls.*

Mark Franklin

compared to stainless steel.

The tools used with endoscopes – the flexible viewing instruments that can be pushed through the body's canals (see NEW TECHNOLOGY page 139) – are limited.

Flexible tools

All the instruments have to be less than 3 mm in diameter, long and flexible so that they can follow the body's natural tracts – the throat, bowel, urethral and genital tracts, and blood vessels. Essentially there are three types of instruments: tiny forceps grip and pull away unwanted tissue; minute electrodes put a current through tissues to burn them to seal blood vessels; and small balloons can be used to open blocked blood vessels and stuck heart valves.

Keyhole surgery

So-called minimum intervention or 'keyhole' surgery – where the surgeon operates through a small incision, rather than a large opening – has also meant that instruments have shrunk. Another development – percutaneous surgery – has seen them get even smaller. Percutaneous surgery is carried out through a tiny pin prick in the skin. Slipped discs in the back are operated on in this way.

Spinal discs can be compared to

James Stevenson/Science Photo Library

Argentum

A surgeon's view *through an operating microscope shows the connection of blood vessels. The free ends of the vessels are clamped (using ligatures) and stitched together.*

The precision *of eye surgery is aided by operating microscopes. Suture thread – no thicker than human hair – is mounted on needles only a few mm long.*

SHADOWLIGHT

Downs Surgical

Because exposure to X-rays can harm tiny infants, surgeons, until now, have had to operate without their help. But a new diagnostic tool has changed all that.

A premature baby's skin is so thin, and its body so small, that a bright light held close to the skin illuminates its insides. Until recently, generating bright light meant generating heat too. Now the 'Shadowlight' keeps the hot light source at a safe distance from the baby by conducting its light down a long fibre-optic tube. The head of the tube is cool enough to press against the baby's skin while the light it gives off is bright enough to shine through its tiny body.

the back – resulting in three months' recuperation in hospital for the patient. Nowadays percutaneous surgery can be performed on a patient under local anaesthetic. The surgeon probes with a 1 mm needle until he finds the point where the doughnut of cartilage is distorted. He or she then begins to slip a series of larger tubes over the needle to open up a gap of between 3 mm and 7.5 mm in diameter.

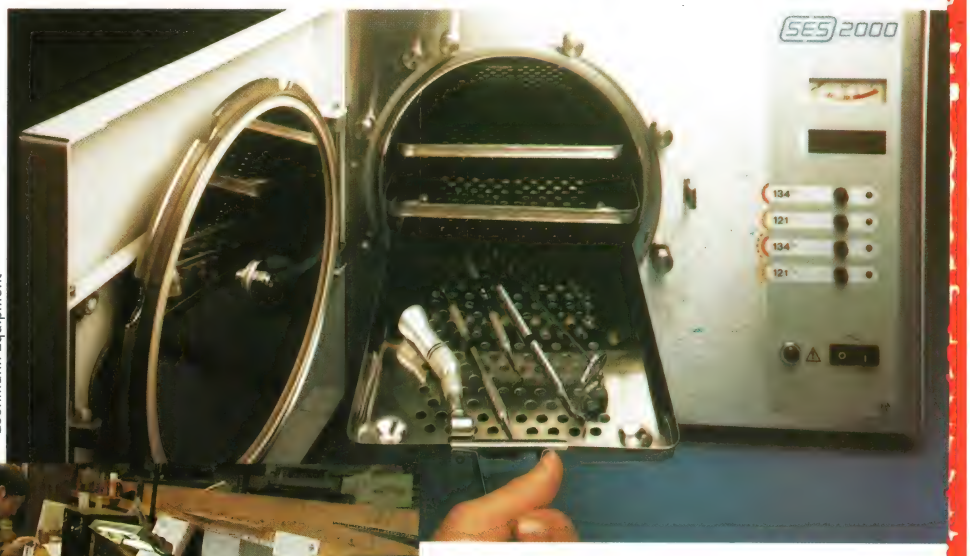
X-ray guides

Tiny retractors can then be pushed down the tube to pull the nerve ending out of the way and tiny burs are used to grind away at the bone, which may also be trapping the nerve. The doctor can see what he is doing on a series of X-rays taken while working

A minute trephine – tiny cutting tool – is then inserted to cut into the cartilage. A tube with a tiny Archimedean screw can also be inserted to drain off fluid and relieve pressure. When the two vertebrae collapse, they fuse together, leaving the patient a little shorter but no longer in pain.

Downs Surgical

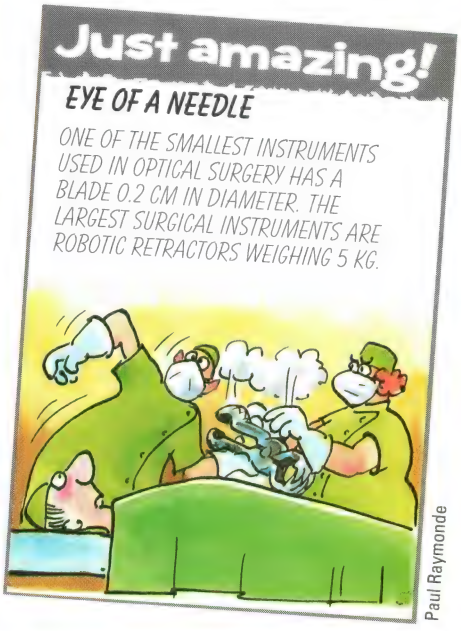
***Dermatomes** are used in plastic and reconstruction surgery to peel off thin layers of skin to the exact depth required.*



Eschmann Equipment

Downs Surgical

***Of the many types** of surgical instruments manufactured, most are used to cut tissues, hold them or suture (stitch) them together again. All instruments are sterilized in an autoclave (above) before use by heating them, via steam, to 134° C for 3 mins.*



Paul Raymonde

the hydro-elastic suspension in a car. Between each vertebra of the back there is a doughnut of cartilage surrounding a reservoir of fluid, which absorbs shock waves.

Slipped discs

Discs do not actually 'slip'. The cartilage simply gets worn and the doughnut distorts and pinches a nerve ending as it emerges from the spine. It is difficult to locate which disc or discs are causing pain and exactly where the problem lies. In the past, a full-scale operation was performed on

Minimum intervention

The advantages of this type of surgery are many. Muscles and outer tissues of the body do not have to be cut. They are just gently forced apart by the series of small tubes. No blood transfusion is necessary and no

Tony Stone Photo Library, London

***Lasers** can be used by surgeons instead of scalpels. They have the advantage of being able to cauterize (reseal) small blood vessels as they cut them.*

wounds require to be stitched up. Rather than spending three weeks in bed recovering, the patient can be back at work the next day.

Endoscopy

Percutaneous surgery can also be used on the knee and to remove kidney stones because the kidneys lie close to the skin. In percutaneous operations on the knee, two tubes are often used – one inserted from either side. Water is forced down one tube to open up the knee joint to give the surgeon a little room to work. An endoscope is pushed down the other tube so that the surgeon can see exactly what he or she is operating on.

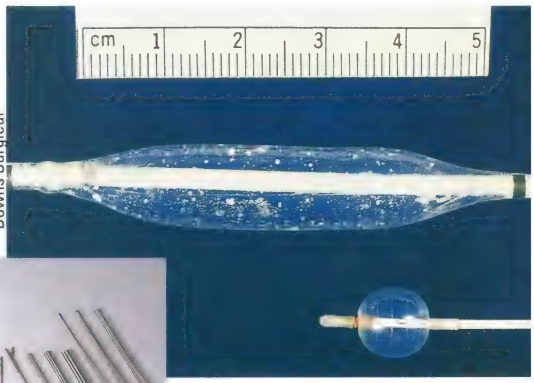
Unlike flexible endoscopic instruments, percutaneous instruments are rigid – often modified or scaled down versions of standard surgical implements. Indeed, many were originally designed for operating on the ear.

Plastic and reconstruction surgery is now widely practised – where skin is cut away from one area for use in other parts of the body. A dermatome is the instrument used to peel off thin slivers of skin ready for transplanting. This is like a safety razor with the distance between the guard and the blade controlled by a micrometer gauge. This sets exactly the depth of tissue that will be peeled off.

Plastic surgery

The largest dermatomes have blades up to 200 mm long, with reversible handles so that they can be used to cut in two directions or by a left-handed surgeon. Smaller ones, the size of regular razors, are used for grafts on the fingers and tiny dermatomes using standard scalpel blades are used to shape, trim and tidy up the finished graft.

Science Photo Library



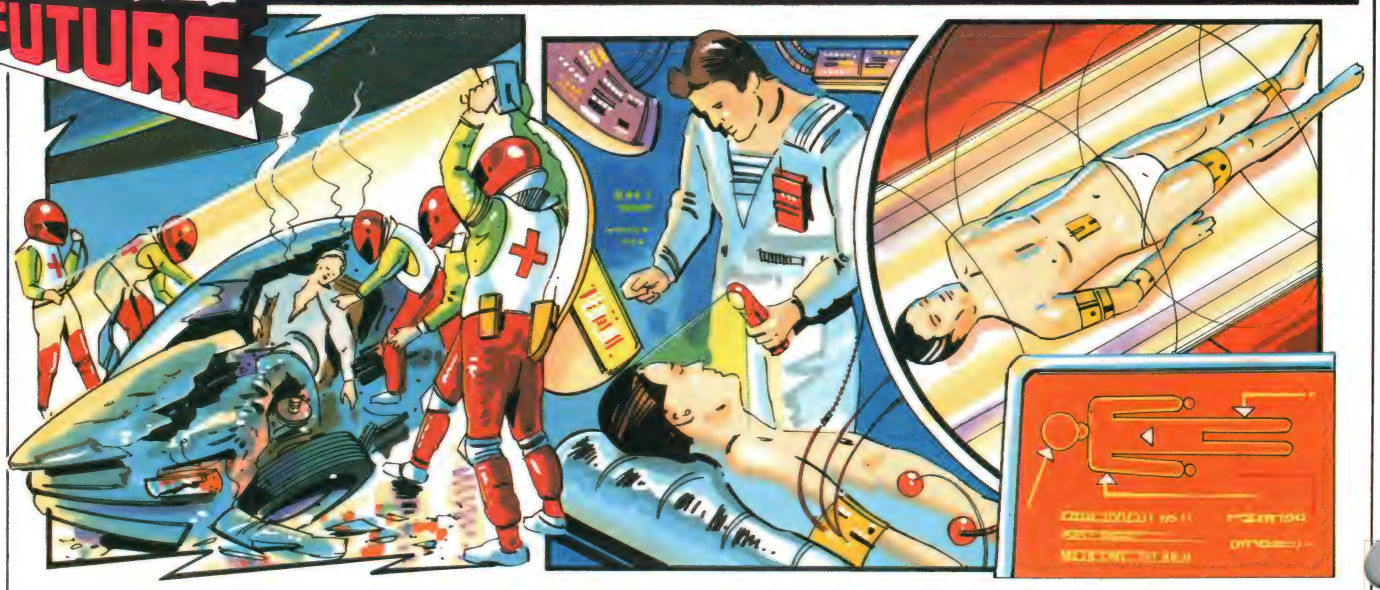
Downs Surgical

***Balloon inflaters**, are used to unblock or widen arteries. Guided into place using enhanced X-ray images, balloons are then inflated to clear a way for blood to flow.*

***Percutaneous operating techniques** require a range of specially designed fine tools. Using them in conjunction with X-rays, surgeons can now operate on, for example, a slipped spinal disc, through a tiny hole in the skin.*

INTO THE FUTURE

THE INVISIBLE HEALING HAND



▲ *Doctors of the future will have at their disposal a battery of non-invasive tools for both the diagnosis and treatment of injury and disease.*

▲ *In casualty a hand-held scanner will be used to pinpoint broken bones and damaged soft tissue, while body functions are watched by a remote monitor.*

▲ *Finally, while all but essential body functions are 'shut down', a molecular accelerator will be used to speed up the body's own healing processes.*

Joe Lawrence

IMPACT ASSESSMENT WIND TUNNELS WATER TANK TESTS

DESTRUCTION TESTING

CARS, SHIPS, PLANES AND bridges – vehicles and structures of all kinds are tested to the limits of their endurance long before they ever reach the user.

Lives and millions of pounds of investment depend on their safe and efficient functioning. Costly programmes of testing begin with models in wind tunnels and water tanks, before risks are taken with the first prototypes.

Much can be learned about a car or lorry before it is ever built by simulating its behaviour on computers. But the final tests, normally to destruction, must be made on the real thing.

Assault courses

A well-equipped vehicle test track has a high-speed circuit, sharp bends and sections with different kinds of surfacing. There are also water-filled dips in some places and stretches that can be constantly sprayed to test braking and steering in the wet. All kinds of 'road furniture' act as hazards for vehicles. There is even a machine to generate sidewinds.

Testing extends beyond performance and handling to the noisiness of the vehicle and the pollution level of its exhaust gases.

Crash recording

When a vehicle is test-crashed it is hauled along by cables. An impact measuring device is mounted on the vehicle and the obstacle that it hits. Cameras filming at up to 10,000 frames per second capture every

Philippe Plailly/Science Photo Library

***Wind tunnels** can simulate adverse weather conditions. The swirling white snow on this model bridge is created by magnesium carbonate.*

Gamma/Frank Spooner Pictures

controlled model boats may also be taken to sea to be tried out in more realistic conditions.

Once a full-scale ship has been built, it must be subjected to sea trials. Its engine power is measured – both when the ship is under way and when it is pulling against a fixed bollard. Its manoeuvrability must be tested – how small its turning circle is and how fast it responds to the wheel. Speed, roll, pitch and yaw are tested, under different sea conditions. A warship's noise-level must also be measured carefully, since this can give away its position to enemy submarines.

Professional downhill skiers *use wind tunnels to assess the amount of wind resistance to their bodies, helping them to achieve faster speeds.*

Philippe Plailly/Science Photo Library

Just amazing!

BOMB THE BASS

SCIENTISTS CAN SIMULATE THE EFFECT OF TEN YEARS OF HEAVY TRAFFIC ON BUILDINGS BY BLASTING THEM WITH LOW-FREQUENCY SOUND SIGNALS FROM MASSIVE LOUDSPEAKER SYSTEMS.

Paul Raymonde

moment of the impact.

Test dummies are a specialized field of engineering in their own right. Their joints imitate those of a real person, so that the stresses and impacts experienced in a simulated crash are as similar as possible to those that a human being would experience in a real crash. Dummies are wired up with force-measuring devices in each area of the body.

Dummies are designed to precise specifications: a side-impact dummy (SID) is different from one used to test the effects of front and rear impacts.

Computer monitor

There is a trend in all types of testing towards amassing huge amounts of computer data for later analysis. One function after another is taken away from human assessors. Even judging the smoothness of a car's ride can be done by a ride meter, a 'black box' that sits on a passenger seat recording the forces that it experiences during a test-ride.

Test pilots

But human beings are still needed in testing. Test pilots, for instance, must not only be above-average pilots, they must also be good at maths and science. They must be able to analyse the behaviour of their aircraft and to give a clear written or spoken report on it afterwards. They must also be very versatile, since they will have to fly many different types of plane.

TRRL

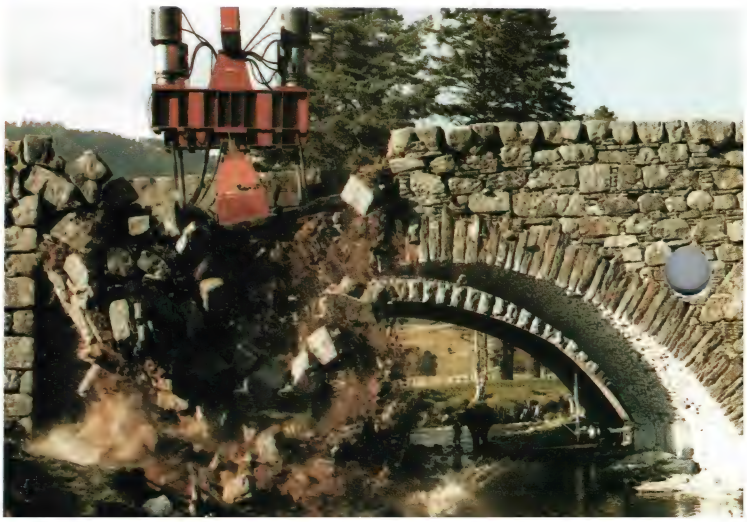
A wind tunnel *under construction. Four metres wide and two metres high, the tunnel is capable of generating an air flow of 100km/h.*

A test plane crash *involves swinging the aircraft from a high structure and then releasing it. The tests show the effects of different types of crash on the human body.*

NASA/Quadrant

Structural testing of, for example, bridges, office blocks and oil-rigs, is just as thorough. Wind gusts can affect the comfort of pedestrians near high-rise buildings, or the stability of a helicopter landing on an oil-rig. For this reason a model of the structure is placed in a wind tunnel to assess its behaviour in winds of varying speeds and directions.

Water-tank tests are used on model ships and oil-rigs. Radio-



Stone bridges, *built hundreds of years ago, are sometimes subjected to heavy pressure from hydraulic pistons so that scientists can assess their ability to withstand vibrations from heavy vehicles.*

DETONATORS NUCLEAR FISSION SEMTEX

EXPLOSIONS

FROM THE VIOLENT eruption of a supernova to the popping of a balloon, all explosions are caused by the abrupt expansion of gas.

Some explosions are caused by combustible materials igniting very rapidly. The burning produces hot gases and also heats surrounding air to produce a fast-expanding blast wave. Coal dust and flour floating in the air can explode in this way. Such materials are described as low-explosive. The resulting shock wave expands faster than sound through the surrounding air, ground or water.

Shockwaves

In other explosives, a chemical reaction creates a shock wave in the material itself that spreads rapidly. A chemical reaction follows closely behind. The material is described as 'detonating'. A great deal of gas is generated very quickly, with shattering effect. A material that normally explodes by detonating rather than by burning is called a high-explosive.

demolition of a water cooling tower. Holes are drilled in the concrete surface at the base of the towers. Each hole is packed with explosive and connected by wire to an electric exploder sited at a safe distance away.

ICI Explosives

DISASTER IN SIBERIA

Alongside the Trans-Siberia Railway in the Ural Mountains (Soviet Union) runs a pipeline carrying liquid natural gas. On 4 June 1989 the gas revealed its destructive potential. A leak in the pipe had allowed large pools of the liquid gas to gather. Nearby residents noticed the smell that morning. So did passengers on two approaching trains. One was packed with children on holiday. As the trains passed, something – perhaps a spark from their wheels – ignited the gas and created a fireball over a kilometre wide. The colossal heating of the air created a blast equivalent to 10 kt of TNT that knocked the trains off the tracks, and stripped trees of their branches for four km around. Over 600 people are estimated to have died.

Today explosives are of great industrial importance. They are used in mining ore, excavating tunnels, capping oil wells – even to shape metals. In warfare, too, different explosives are used for different tasks.

An important principle in the use of both military and industrial explosives is that the main charge is insensitive (difficult to detonate). The charge is triggered by a small quantity of a substance that is easier to detonate – that in turn may be detonated by a still smaller quantity of a still more sensitive substance.

Plastic explosives

The most widely used industrial explosive – ANFO – consists of small spheres of ammonium nitrate impregnated with fuel oil. Others are gelatinous (jellylike), or powdered.

Plastic explosives are powdered explosives combined with other substances to make a putty-like material. Because this can be moulded and shaped, it can be readily concealed. Semtex is much favoured by terrorists because of this. It is also relatively hard to detect by dogs, sniffer machines or X-ray detectors.

All chemical military explosives are overshadowed by nuclear weapons. Their strength is expressed in kilotonnes (kt = thousands of tonnes) or megatonnes (mt = millions of tonnes) of TNT. For comparison, Second World War bombs had an explosive power of only a few tonnes of TNT.

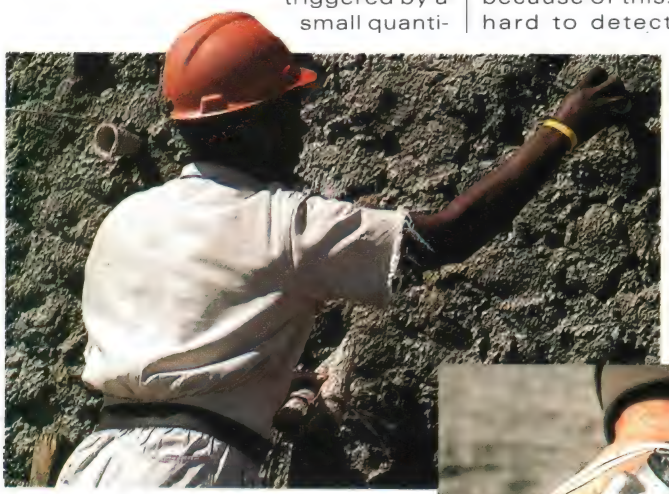
The most powerful nuclear weapons ever created are the USSR's SS-18s, believed to be armed with ten 750-kilotonne multiple independently targettable re-entry vehicles (MIRVs). The US Titan II, with a W-53 warhead rated at 5 to 9 megatonnes, was withdrawn leaving the 1-2 megatonne W-56 the most powerful US weapon.

Krakatoa

The most devastating natural explosion in recorded history occurred on 27 August 1883, when a large part of the volcanic island Krakatoa, in Indonesia, blew up. Over 36,000 people are estimated to have been drowned by the ensuing 'tsunami' (tidal wave). For months there were spectacular sunsets because of the dust lifted high into the atmosphere by an explosion estimated to have had the equivalent force of a 1,500 megatonne bomb.

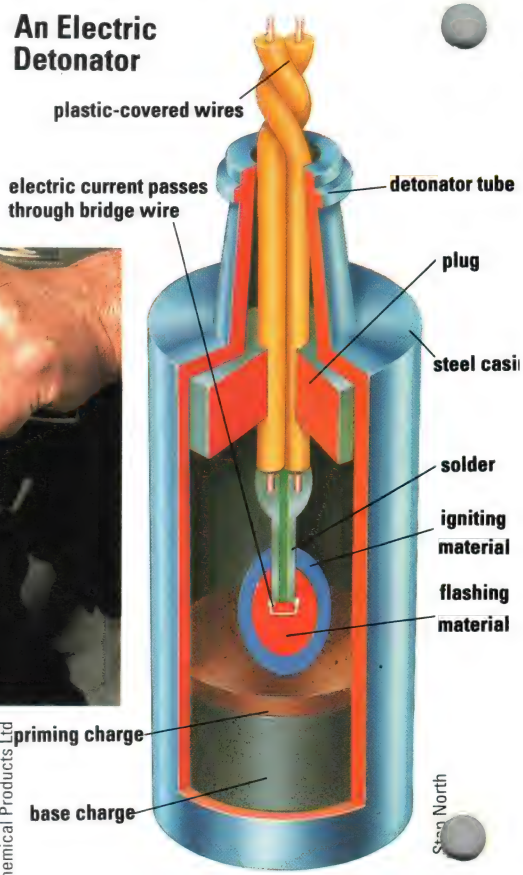
***A simulated coal dust** explosion carried out by the Health and Safety Executive, UK. Coal dust is injected into the explosion chamber and ignited by a black powder charge. A blast of this force can be created by 1/2 kg of coal dust per cubic metre.*

Health & Safety Executive



***A gold miner** positions a detonator and explosive. Detonation can be effected by heat (fire), by impact or by an electric spark, set off by a hand-held exploder (below).*

An Electric Detonator



Stan North

***In electric detonators,** an electric current passes through the bridge wire and sets off the surrounding explosive.*

Explosives & Chemical Products Ltd

Just amazing!

BIG BANG!

THE MOST POWERUFL H-BOMB EVER TESTED WAS A SOVIET ONE OF 57 MEGATONNES. POWERFUL SHOCK WAVES FROM THE EXPLOSION CIRCLED THE EARTH THREE TIMES.

Paul Raymonde

PAVING THE WAY

- MACADAM
- TARMAC
- ASPHALT

ROADS ARE AN ESSENTIAL part of our lives. They link our towns and cities and we walk or drive over them every day. Yet we take them for granted most of the time and it is only when there are delays caused by road repairs that we realise how important they are.

Although basic roads had been built in China and Asia after the invention of the wheel, it is generally accepted that the first great road-builders were the Roman armies that conquered much of Europe and Asia nearly 2,000 years ago. They were the first road builders to 'camber' the roads. The sides of a Roman road sloped down from the centre so that rain water ran off.

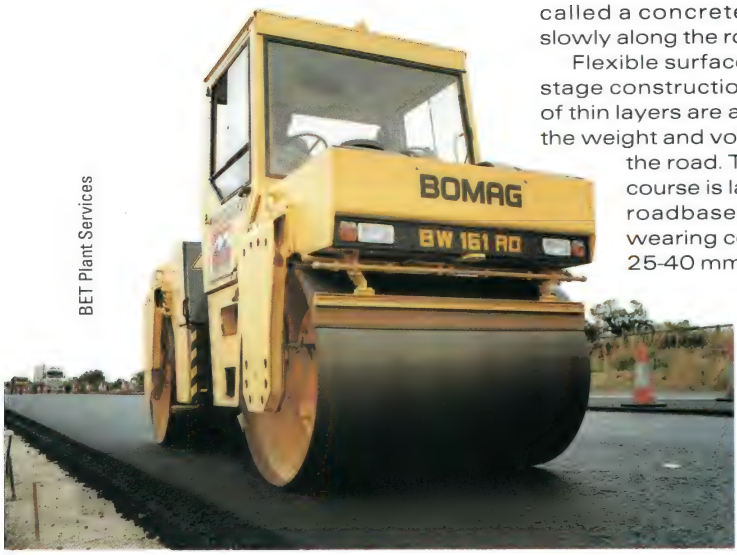
'Macadam'

The great leap forward in road technology came in 18th-century Britain through the two Scottish engineers Thomas Telford and John McAdam. McAdam revolutionized roadbuilding by introducing the system that is still used today.

Roads are made up of a basic layer of stone that has been broken up into different sizes, known as aggregate. McAdam was the first to realize that a combination of small and large stones made the most compact and solid road, because the smaller stones filled in the spaces between the larger stones. This basic material is called 'macadam'.

***Roads are a vital** means of communication. Their construction is time-consuming and costly, and they must be able to stand even the most hostile environments. They must also be able to withstand heavy urban traffic (right).*

Tony Stone Photo Library, London



BET Plant Services

A 'road roller' is no longer driven by steam. Modern 'compacters' have diesel engines. They follow the paver and smooth the finish.

called a concrete train that travels slowly along the road.

Flexible surfaces can be laid using stage construction, where a number of thin layers are applied according to the weight and volume of traffic using the road. The 45-60-mm base course is laid directly on to the roadbase and is topped by a wearing course that is around 25-40 mm thick.

The flexible surface – known as 'blacktop' – is laid when it is hot by a mechanical finisher. It is then compacted with rollers as the finisher moves along. The rollers may be smooth-wheeled, pneumatic-tyred or vibrating – most are diesel-engined.

Blacktop is usually delivered to the site from an automated plant where the correct amounts of graded aggregate have been weighed by computer, heated and mixed.

The sub-base is made from crushed and compacted stone or gravel up to 600 mm thick, although in some concrete roads it is left out.

Flexible joints

The roadbase of a rigid pavement is made up of slabs of 'lean cement concrete', often reinforced with steel. This has a low percentage of cement, and the slabs must have flexible joints at regular intervals to allow for expansion caused by hot weather.

In flexible pavements, the roadbase must also be flexible and is made up of layers of coated materials that are laid by a mechanical finisher.

***Motorway bridges** are made of reinforced concrete and effortlessly span distances unthinkable in other materials.*

It is then compacted using heavy rollers. This type of roadbase is sometimes used under rigid surfaces, making up a composite construction road, often found on airport runways.

The surface of a rigid construction is made up of slabs of concrete up to 250 mm thick. The sections of concrete are called bays, with expansion joints in between that are filled with a flexible and waterproof bituminous compound. The road is laid in a continuous process by a special machine

The binders

The type of binder used – bitumen, tar or a mixture of both – depends on several factors. One is the stiffness – or viscosity – of the binder, which can vary with temperature. So weather conditions have to be taken into account. Another factor is that bitumen is oil-based and is soluble in oil. So in areas where oil or petrol are likely to be spilled, such as garage forecourts, high-viscosity tar is used.

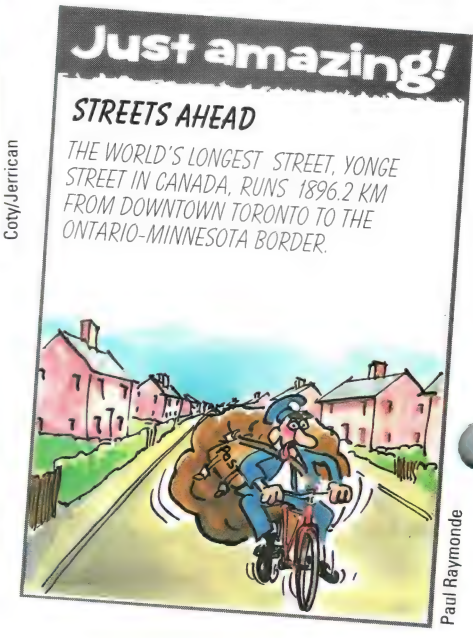
To give extra grip on the wearing surface, a final coating of asphalt with pre-coated chippings rolled into it is applied. This anti-skid surface is used for main roads and motorways.

CAT'S EYES

The final touch in roadbuilding is to add road markings, such as white lines. These are painted down the middle of the road using reflective paint. For extra safety where there is little or no lighting, reflective 'cat's eyes' are embedded in the surface. These are not cat's eyes at all, but glass or plastic prisms that reflect oncoming car headlights and mark the way. They are also flattened back into the road, so that they do not get damaged or stick out dangerously.

***A new surface** called Permflex, used on the left carriageway here, incorporates thermoplastic rubber in the bitumen to improve drainage and cut down spray.*

Shell



Coty/Jerrican

Paul Raymonde

HYDRAULIC TOOLS THERMIC LANCES RECYCLING WASTE

THE CRUNCH BUNCH

CONSTRUCTION INDUSTRIES today are coming to rely heavily on demolition. As land and raw materials become increasingly rare, the manufacture of tools used in demolition and the recycling of the rubble left behind is now a rapidly expanding industry.

Years ago, demolition involved knocking down buildings and dumping the rubble created. Until recently in Britain alone, around 20 million tonnes of demolition rubble was being dumped annually at a cost of £50 million. At the same time, huge sums of money were being spent on digging up hardcore for use in the foundations of roads and buildings.

Now, much of the waste produced by demolition is recycled. Bricks, which are expensive to buy new, are being cleaned up and rubble is being used again as hardcore.

Conventional demolition equipment – the swinging ball and sledgehammer – was found lacking when faced with modern structures of steel reinforced concrete.

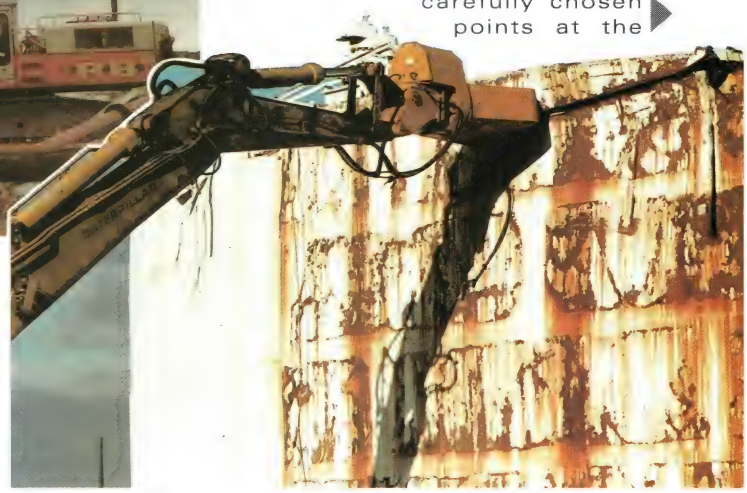
Tony Stone Photo Library, London

Explosive charges *have been used to remove key parts of this electric power station, causing the building to collapse under its own weight.*

Peter Menzel/Science Photo Library

Holes for explosives *are drilled under expert supervision in precisely planned positions for this potentially dangerous demolition procedure.*

Allied Construction Equipment Ltd



Hydraulic shears *can handle tasks from dismantling steel beams to cutting thick metal sheets. Their long reach allows the operator to work at a safe distance.*

Now a wide range of crushing and cutting machines is available, and demolition techniques have become so advanced that the interiors of fine buildings can be completely gutted without damaging the facades or surrounding areas.

If a building is located in an area well away from surrounding structures, demolition can be carried out by weakening key points of support and forcing the building to collapse.

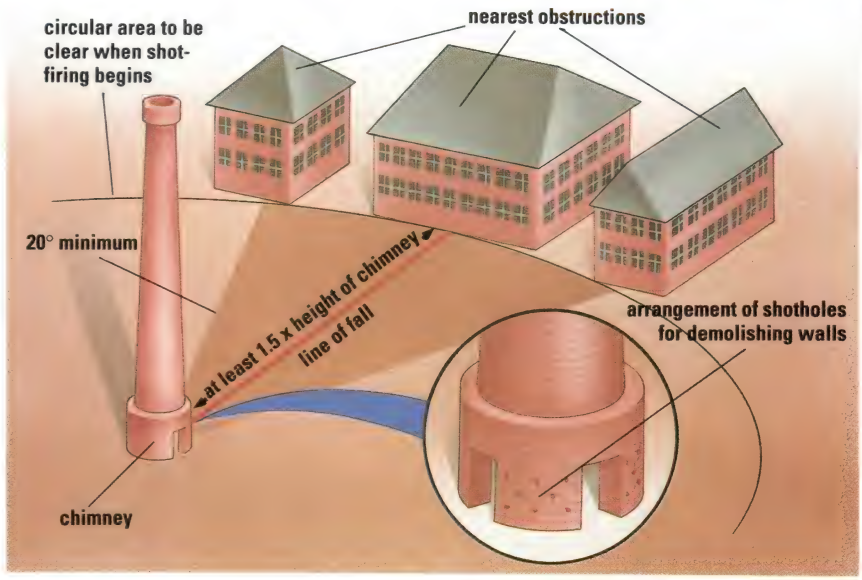
ZEFA

A demolition ball *in use. The ball can be dropped vertically on to horizontal surfaces such as floors and roofs, or swung against walls.*

Thermal reaction

Collapse can be induced in steel structures using the thermal reaction process. This involves packing a mixture of a metal oxide and a reducing agent around the girders or columns of a building that is then ignited electrically. The heat generated by the reaction softens the steel supports which can then be pulled with ropes bringing down the rest of the building.

One of the most effective ways of causing a building to collapse is by using explosives. Charges are laid in carefully chosen points at the



Allied Construction Equipment Ltd

Mark Franklin

A clear line of fall *must be established to demolish a chimney safely with explosives. Charges are laid on one side of the base to control the direction of its collapse.*

Krupp Maschinentechnik

The hydraulic hammer *combines an hydraulic drive system and a nitrogen pressure accumulator, making it a powerful and highly versatile demolition tool.*

Goodwin Barsby

***Crushing and cleaning** are done at the same time in a crusher, while grid bars in the front section allow undersize material to fall from the feeder.*

base of the structure so that when supporting walls are blown away the building collapses.

The tools used for demolition may be hand-held for smaller jobs or attached to motorized vehicles for larger ones. Hydraulic tools can generate enormous pressure with their various attachments.

The first tool used in the demolition process is often a jack-hammer which breaks up or pulverizes concrete. It is attached to a flexible, jointed arm that is mounted on a purpose-built tractor-like vehicle. This vehicle has to be sturdy enough to move around on a rubble-strewn demolition site – which usually means that it is fitted with caterpillar tracks instead of wheels.

Another way to demolish concrete is to use a huge and powerful pair of mechanized jaws, called a pulverizer, to snap off sections of concrete.

To cut any steel reinforcement, a demolition contractor may use oxy-acetylene torches or hydraulic shears.

***Special clothing and goggles** must be worn when using a thermic lance as protection from the hot flame it uses to cut through steel and concrete.*

BOC Gases

Steel and concrete

The shears are mounted on a vehicle for maximum manoeuvrability, whereas torches are hand-held. The torches combine oxygen and acetylene or propane and can cut steel up to 30 cm thick.

Steel and concrete over 30 cm in thickness require the use of an oxygen-powered thermic lance. This is a long steel tube filled with steel rods. The end of the tube is preheated and oxygen is passed through it, reacting with the steel at the heated end and creating an intensely hot flame that can cut through steel and concrete.

Once the main structure has been reduced to rubble, it is cleared away using motorized scoops and loaders and transported away in lorries.

The emphasis on recycling has led many demolition contractors to install crushing plants which reduce rubble to workable-sized pieces for hard-core. Materials such as wood and brick are also salvaged and can be separated by running them through a tank of water in which the wood floats and the brick sinks.

TRICKY SITUATIONS

For delicate excavation work on a site where pipes or cables in the ground may be cut by digging equipment, a high-velocity compressed air hose can be used to blow away or extract soil without any risk to the pipes, cables or operator. The opposite effect is obtained with an excavator, which uses high-velocity compressed air to create a vacuum, picking up water, soil and rocks up to 10 cm in diameter.

Industriebau-Dederichs GmbH

***A rubble sorting plant** sifts out materials such as brick and stones from the refuse left after demolition so that they can be recycled.*

Paul Raymonde

Francis Leroy, Biocosmos/SPL

Cancer cells, *if malignant (bad), build up into tumours that compress, invade and destroy normal tissues.*

Tiny blood flukes *are carriers of bilharziasis. Infectious to Man, they pierce the skin and travel through the bloodstream to mature and mate in the liver.*

Termites *– ant-like insects – may survive exclusively on wood and flourish in the tropics. A colony of a million or more on a feeding march destroys acres of trees.*

London Scientific Films/Oxford Scientific Films

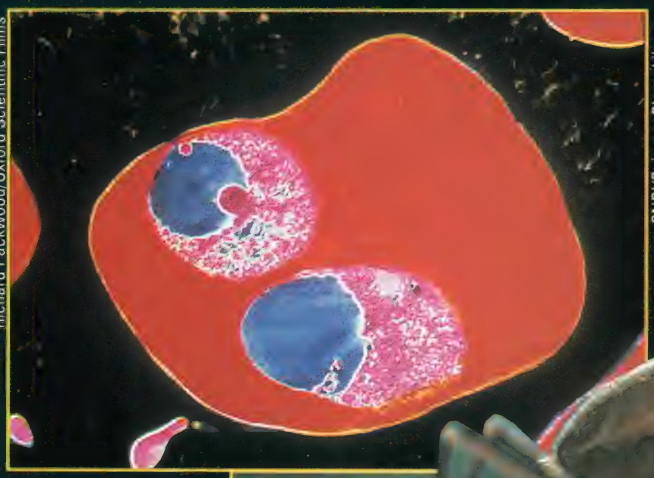
Dry rot fungi *play a vital role in woodlands of breaking down aged trees. When attacking the timber of buildings it can cause major structural damage.*

Kim Taylor/Bruce Coleman Ltd

A furniture beetle *emerges from infected wood. 'Woodworm holes' are the exit tunnels of beetles that have matured from woodworms living in the wood.*

Cair Ellis/SPL

Jane Burton/Bruce Coleman Ltd



Richard Packwood/Oxford Scientific Films

CNRI/Science Photo Library

Locusts *in modest numbers do little damage to vegetation, but a swarm will devour all in its path.*

London Scientific Films/Oxford Scientific Films

Infected mosquitoes *deposit malaria parasites as they suck blood from a host. The parasites release merozoites that enter red blood cells and the victim contracts malaria.*

Q MOBILE CRANES Q COUNTERBALANCE Q TELESCOPIC ARMS

Jib cranes *for operators with a head for heights, at Canary Wharf, London, UK. Their lifting capacity and wide reach make them extremely useful on construction sites.*

GIANT HANDS

Tony Stone Photo Library, London

CRANES ARE ESSENTIAL IN THE construction industry. Without them, many huge modern structures would not be possible. No better method of lifting heavy loads has been found.

There are many different types of crane and the model used is selected according to the purpose for which it is required and the size of the load to be lifted. Some are stationary, while others are mobile and may be transported from site to site. They are usually made of heavy-duty tubular steel, sometimes octagonal in cross-section for extra strength.

Pulley system

All cranes operate in the same basic way using the principle of pulley systems to lift loads. Their lifting apparatus is attached to steel cables, or chains that pass through pulley systems and are wound on a drum, known as the hoist. The ability to lift and displace loads horizontally as well as vertically is the distinguishing feature between cranes and other simple lifting devices.

Bridge cranes

The two main types of crane are bridge – or portal – cranes and jib cranes. Within these divisions there are numerous varieties. Bridge cranes include overhead travelling cranes and Goliath cranes. Among the types of jib crane are tower cranes; telescoping boom cranes; scotch derrick cranes and level luffing cranes.

A bridge crane has a trolley or cab that travels along the overhead bridge and carries the lifting mechanism. The horizontal bridge is supported on legs – in cases where the legs are equipped with wheels which run on parallel rails or tracks, the cranes are known as Goliath cranes.

Independent wheel suspension *is one of the innovations in crane manufacture that increases manoeuvrablity of mobile cranes on difficult terrains.*

Overhead cranes

The most commonly used bridge crane is the overhead travelling crane found in factories, power stations and areas where floor space is restricted. The hoisting apparatus travels back and forth across the width of the working area on an overhead bridge made of steel girders. The bridge itself

Krupp Industrietechnik

Computer analysis *is applied to various aspects of crane manufacture. In the case of box beams for overhead cranes, this has resulted in improved welding techniques to give higher rigidity and less load bounce.*

mobile. They can be assembled quickly on site in sections to make what are known as tower or cantilever cranes, that resemble a giant 'T' shape. These are the cranes that are visible in urban skyscapes rising 100 metres or more over major construction sites.

Cantilever cranes consist of a tall vertical latticework tower with a main jib extending out at 90° to the tower, and a smaller, shorter jib extending in the opposite direction holding a

A mobile crane *in the process of assembly with the use of an overhead crane to lift and position the crane operator's cab.*

Street Crane

can travel the length of the building on trolley wheels along an elevated framework (gantry), which supports it at each end. The gantry is built against the walls of the room, or alternatively is a structural part of the building's framework. Thus the crane can pick up a load and put it down anywhere in the room without taking up any floor space itself.

Overhead travelling cranes *maximize restricted space. Over-hang rotating trolleys can cover the entire floor area.*

Aumund GmbH

The positioning of the hook or winch can be automatically programmed or manipulated by an operator, either directly or by remote control. Remote control operation using television cameras is especially important in areas hazardous to humans. This means that the operator does not have to be positioned near the crane or its load; he or she has, therefore, greater flexibility.

Jib cranes

The other major group of cranes – jib cranes – is used mainly in construction. These have an arm, the jib or boom, that can move up or down and rotate about a central point, an action called slewing. This gives them great manoeuvrability and makes them especially useful in confined areas.

Jib cranes are also generally

A telescopic crane, *the TM2500, is a massive 16-wheeled juggernaut capable of lifting 225 tonnes. The telescopic boom consists of five sections that can extend from 14 m to 53 m in ten minutes. The crane operator has joystick remote controls for crane functions and switches for the telescopic boom. Pressure switches activate warning systems in case of overload.*

Trevor Hill

Grove

Liebherr Great Britain Ltd

***A telescopic crane** at work on a demolition site. To minimize the risk of overturning, counterweights are an essential part of a truck-mounted crane's operating equipment. These are visible positioned at an angle of 180° to the jib, where they offer the greatest leverage.*

heavy counterweight. Sometimes the counterweight is in the base of the tower attached to the jib with cables. The lifting cables are attached to a trolley that travels along the main jib, and are operated by the turning of a huge motorized drum. These cranes can lift up to 150 tonnes.

Lifting capacity

For greater mobility and flexibility, self-propelled cranes can be driven directly from job to job on caterpillar tracks. Usually smaller than tower cranes, they are more versatile and can lift much heavier loads, sometimes up to 1,000 tonnes.

Jeremy Trew/Science Photo Library

***Loading cranes** moving freight containers at Felixstowe docks, England. Major ports utilize quayside cranes mounted on rails that run parallel to the quay, thus allowing them to be moved alongside any berth. Lifting capacity can reach 40 to 50 tonnes.*

Some cranes are mounted on the back of huge trucks, which have extension arms to help stabilize the crane when in use. These trucks may have eight axles and sixteen wheels or more, because of the weight needed to keep the crane stable.

Counterweights

One of the major problems associated with jib cranes is that they have to counterbalance the huge weights they lift. Because they are not supported by columns either side of lifting gear, as bridge cranes are, they need to be balanced by enormous weights (usually blocks of concrete) to prevent them from toppling over when lifting heavy loads.

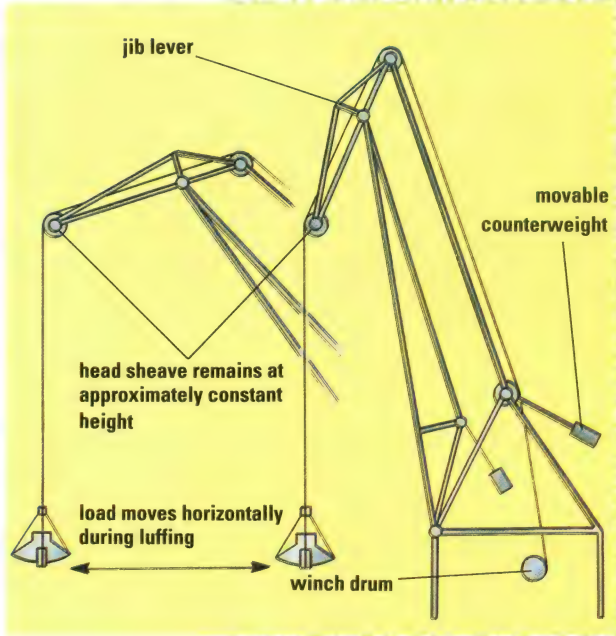
Tower cranes have heavy steel or concrete counterweights set out opposite the lifting arm. Road cranes have the same sort of counterweights mounted in the base or substructure, often with cables running up and over the jib to act as a cantilever. Cantilevering arrangements can be quite complicated, with several sets of support cables working together.

The stability of the crane is measured in terms of its safety against overturning. This is carefully calculated so that the crane is not overloaded and in danger of toppling.

Safety equation

This 'overturning moment' is worked out by multiplying the weight of the load by its radius – the radius is the distance from the load to the king pin of the support tower. The radius in turn differs according to the slope of the jib, so that when the jib is raised steeply, the radius is small and the crane can carry a heavier load than with a larger radius.

THE HEAVY LOADER



Mark Franklin

The upwards and downwards movement of a jib arm is known as derricking or luffing. But for some specialized operations such as loading and unloading from ships at ports, a level-luffing crane is necessary. In this type of crane, the load moves in a horizontal path as the jib is raised or lowered. This is achieved by using an extra section at the end of the jib called a jib lever that acts to compensate the luffing movement. As the jib swings up, the lever tilts down by using movable counterweights to keep the load at the same height. An added advantage is that the projecting lever gives extra clearance from the main arm when handling bulky loads.

The calculation of the maximum radius multiplied by the weight of the load gives the crane its maximum lifting capacity. This maximum must never be exceeded.

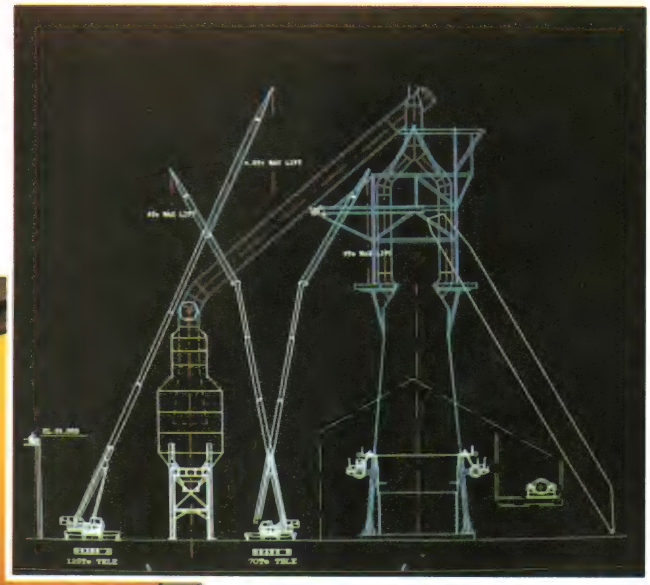
Attachments

Cranes do more than just lift; they can use a variety of attachments for specific jobs. The most common attachment is the hook for lifting, but cranes can also have grabs, buckets

and even platforms for standing on.

The grab is used for lifting quantities of loose material such as soil or coal. Its two shell jaws open and close by operating a holding and a closing cable in turn.

To give cranes extra height and manoeuvrability, they can have extending telescopic arms or articulated arms with several joints allowing them to move in several ways. A telescopic jib crane will drive to a site with its jib retracted and flat. Once in position, and with the stabilizing arms set out, the main jib is lifted by hydraulic rams attached to a fly jib beneath it.



***Computer simulation** of a crane lift. The objective is to find the most efficient way to move a load and test the feasibility of proposed equipment.*

BET Plant Services

Aumund GmbH

***Remote-controlled operation** of lifting and placing loads enables precise positioning to the nearest millimetre – especially useful in work areas that are hazardous to humans and in areas where sterile conditions are required. Hand-held remote-control systems (right), allow the optimum position for viewing the load.*

Street Crane

Weight distribution

Once at the required angle, the jib can extend out to its full length and the lifting can begin. The lifting gear consists of heavy-duty steel cable wound round motorized drums, with a system of pulleys to spread the load-driven across the whole cable, thus reducing the strain on any one point.

Nearly all jib cranes are operated from a cab; for a tower crane the cab is usually at the top of the tower but for mobile cranes the cab is usually close to the ground, situated on the substructure. Where the cab is at a high level, there are strict limitations as to the weight of the load lifted. This safety limitation is often controlled by 'safeload' indicators inside the cab. The operator has an array of buttons and levers to move all the various parts, usually by hydraulic action, although servo motors and electric drives are used as well.

Operating a crane is a skilled and potentially dangerous business, so the drivers have to be well-trained and safety-conscious. A trainee spends six months with a trained operator and must attend courses.

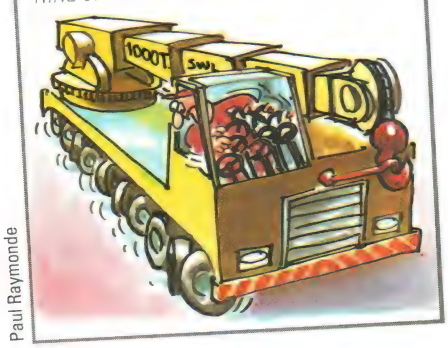
Automatic cut-out

As cranes carry heavier loads, so increasingly sophisticated manufacturing technology is employed in their design, producing such safety innovations as an 'overload cut-out'. This electro-mechanical load cell is built into the hoist diverter assembly so that if an operator attempts to lift more than the safe working load the motors that drive the hoists cut out.

Just amazing!

POWER STEERING

THE WORLD'S LARGEST TELESCOPIC TRUCK CRANE, WITH A LIFTING CAPACITY OF 1,000 TONNES AND A SPEED OF 72 KM/H, HAS TEN AXLES – NINE OF WHICH ARE STEERED.



Paul Raymonde

Q OFFSHORE LOADING Q LASH VESSELS Q TRANSPONDERS

PORTS OF CALL

The port of Singapore *is the busiest in Southeast Asia. As a free port, there is no payment of import duty on goods being unloaded and reshipped.*

Vessel traffic management *is fully computerized. The screen showing vessels in transit zooms into a specific area by responding to finger pressure.*

Sperry Marine

ADVANCES IN THE WAY cargo is carried by sea have revolutionized ports and harbours. New methods of handling goods and provisions for very large ships are among the most obvious changes.

Over the last 40 years, the number of passengers travelling by sea has fallen dramatically due to competition from jetliners. Yet ships still reign supreme for transporting bulky or heavy cargoes between continents.

In the past, dockyards employed large numbers of people for loading and unloading. Goods were generally packed in small crates or sacks and either carried down gangplanks or slung from simple cranes in nets or baskets. It could take 25 dock workers a week to load or unload a large vessel carrying a loose cargo like this.

Container handling

Today, many items are pre-packed for shipping in large, standard-size metal containers at a factory. These are delivered to the port by lorry or train, then lifted off by a special crane known as a straddle carrier.

Each container is put on a marked space on the dockside. A giant

Tony Stone Photo Library, London

Tony Stone Photo Library, London

A giant gantry crane *for lifting containers dominates the quayside in Singapore. Ships en route to Japan, China and Australia unload and load here.*

Mura/Jerrican

A standard container *being transported by a forklift truck at Marseille, France. Once unloaded, goods are moved to adjacent road or rail terminals.*

gantry crane then loads the containers aboard. Using a computer for accurate positioning, the crane operator can load or unload about 30 containers an hour. These are stacked close together and on top of one another in such a way as to spread the weight evenly over the whole of the ship's hold.

The largest container ships can carry up to 4,000 containers, holding everything from clothing and computers to tennis racquets and television sets. In some cases, containers are stacked about the main deck while a variety of other cargo is stored in the holds below. Parts of the ship may be refrigerated to keep perishable foodstuffs fresh during the voyage. Previously, goods such as bananas were packed unripe in crates so that they would ripen en route, although many simply went bad.

Other types of cargo are now also handled in a much more efficient way. Oil, for instance, instead of being loaded and unloaded in barrels, is simply pumped into and out of the huge tanks of a supertanker. Similarly, grain is carried loose and unloaded at great speed by powerful suction tubes rather than being hoisted out tediously in sacks by a crane.

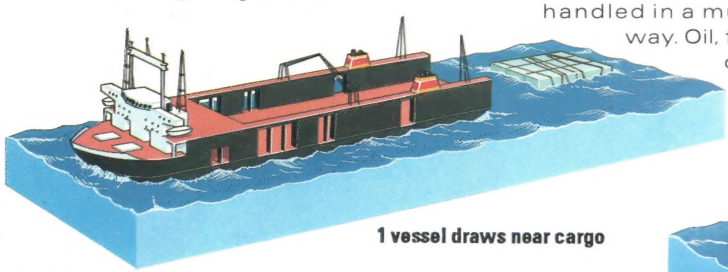
Supertankers

The size of vessels carrying bulk cargoes, such as oil, liquefied natural gas, ore, and grain has also increased tremendously. Currently, the largest ship capable of carrying dry cargo is the Norwegian ore carrier *Berge Stahl*, with a deadweight of 364,767 tonnes and a length of 343 metres. Supertankers can be even larger – up to half a million tonnes. Such enormous ships require special deep water channels and unusually long berths to be able to dock.

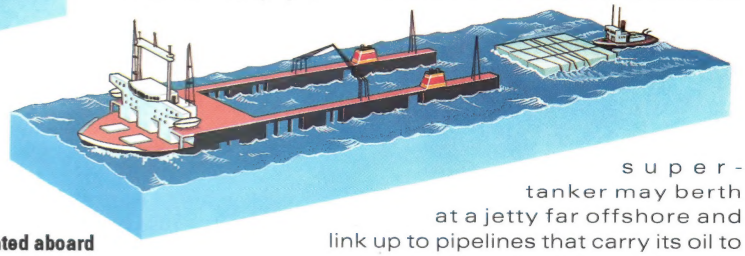
An alternative way of loading and unloading supertankers is to use offshore facilities. Oil and gas may be piped from a production site to massive underwater storage tanks. The supertanker moors to a floating buoy located in the sea directly above the storage tank and has oil pumped aboard through flexible pipes. In other cases, the oil is pumped directly to the buoy from the production site and then straight on to the ship.

To unload at its destination, the supertanker may berth at a jetty far offshore and link up to pipelines that carry its oil to storage tanks on land. From these, the crude oil is piped to a refinery.

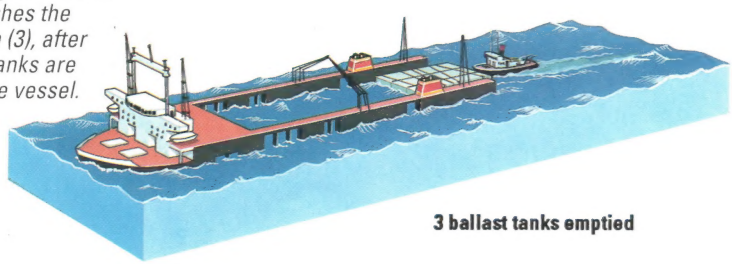
Loading Sequence



1 vessel draws near cargo



2 cargo floated aboard



3 ballast tanks emptied

A LASH *(Lighter Aboard Ship) vessel. To load lighters, the lighter is positioned behind the ship (1). The LASH vessel is lowered by flooding the ballast tanks (2). A tug pushes the lighter into position (3), after which the ballast tanks are emptied to raise the vessel.*

Jeremy Banks

Lighters

Another way of getting cargo to smaller ports is by a type of vessel called a LASH, or Lighter Aboard Ship. Barges, or lighters, are loaded up at a shallow-water port, often inland, and then towed to a deep-water port.

There, the LASH takes the lighters on board by partly flooding its hull. At the next port, the lighters float off again, carrying their cargo by river or canal to its final destination.

Ro-Ro Ferries

Passenger terminals, linked to high-speed roads and railways, are now able to handle huge volumes of car, coach, lorry, and rail traffic. Many ferries are of the Roll-on Roll-off (Ro-Ro) type, so that vehicles can be driven on and off them without delay. Hinged doors at the bow are swung open and steel ramps lowered to give easy access to parking spaces in the hold. Then, when the ferry reaches its destination, the stern of the ship hinges back to let the vehicles drive out in the direction they are facing. A reappraisal of this design of craft was begun after the ferry *Estonia* sank in the Baltic Sea in 1994 with great loss of life.

No captain can know the details of every port or harbour, so usually a pilot comes out to a large ship to help steer it in safely. The pilot has a detailed local knowledge of the port and its waters, including the exact position of deep water channels.

Automatic guidance

More and more major ports are being equipped with automatic guidance systems for ships. Two rows of bleeping transponders moored to the seabed mark the sides of the channel that the vessel must follow. Other transponders, fixed to the ship's keel, pick up these signals and use them to control thrusters under the stern and bow. By this means, the ship steers itself into port automatically down the proper course or 'fairway'.

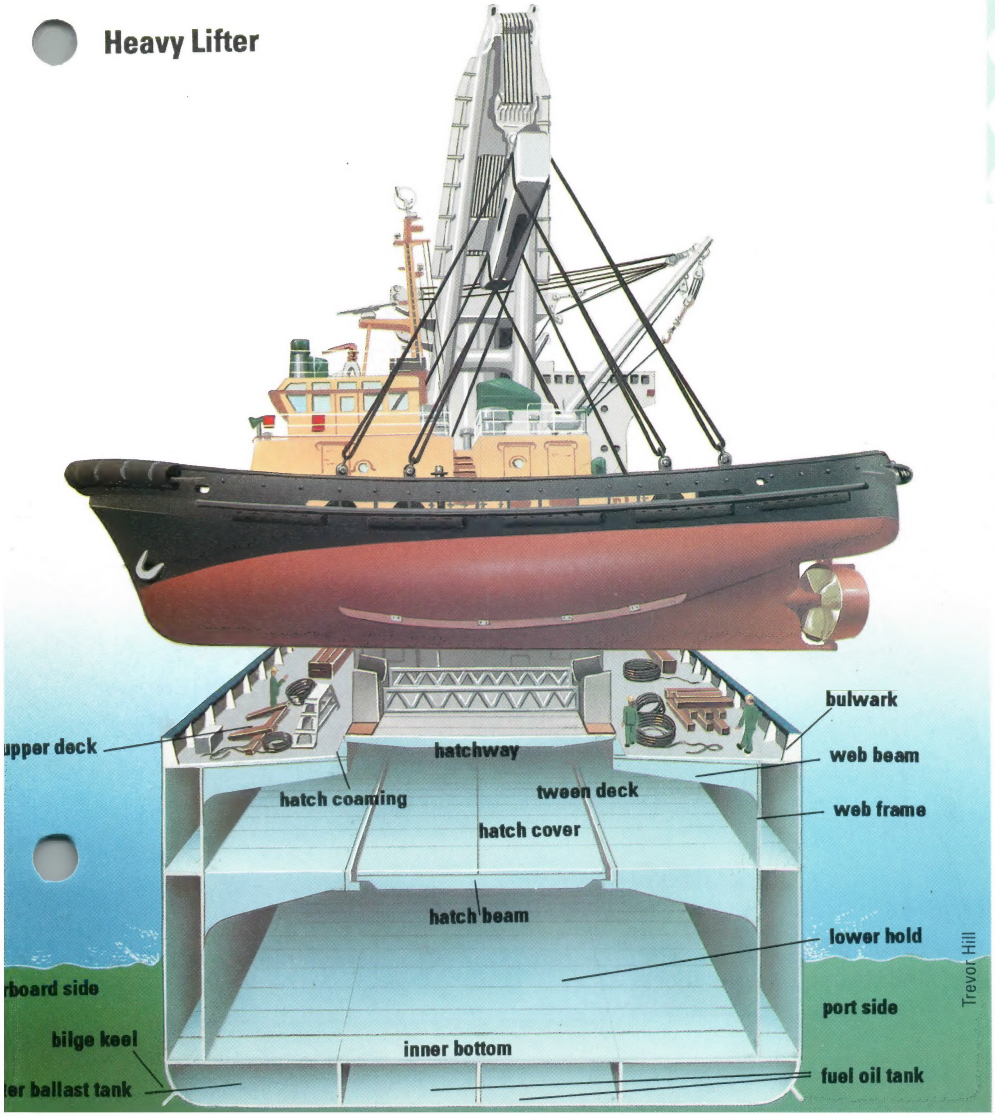
Large vessels are difficult to stop and manoeuvre in confined spaces.

The Atlantic Forest *– a LASH vessel – can carry 83 loaded lighters, each of which can accommodate 380 tonnes of cargo. In a port such as Rotterdam, the lighters can sail directly to upriver ports and inland waterway destinations.*

Foto Flite

A Heavy Lifter *vessel for transporting bulky and awkward packages. The top of the bulwark is designed to be the same height as the top of the hatch covers so that lengthy pieces of cargo can be stowed across the deck.*

Heavy Lifter



Trevor Hill

PORT SECURITY

Gamma/Frank Spooner Pictures

Ships entering port from foreign countries are checked thoroughly to make sure they are not carrying illegal immigrants, goods or dangerous diseases. Customs officers board a vessel before it docks to see that no one on board is ill, or lacking proper authorization and to search for smuggled goods, such as drugs or weapons. After docking, the cargo is unloaded and may be inspected again. Above, the US Seventh Coast Guard, whose headquarters are in Florida, conduct a search operation. The huge area covered by these guards interfaces with 24 foreign countries and the majority of law enforcement cases conducted in district waters involves the interception of drug smugglers.

Other responsibilities of the coastguards are to ensure the safety of vessels, to protect waterfront facilities from damage, to monitor pollution incidents and enforce pollution laws.

Robert Harding Picture Library

Rex Features Ltd

Los Angeles *is the busiest port on the west coast of the USA. It covers about 3,000 hectares making it one of the largest artificial harbours in the world.*

For this reason, tugs are used for the final stages of bringing them in and out of port.

Though small, tugs have extremely powerful engines. The most powerful, the *Wolradd Waltemade* and her sister ship *John Ross*, are 94 metres in length and rated at 19,200 shaft horse-power. As well as towing barges and bigger ships, tugs can be called on for emergency work. For instance, after a tanker accident, tugs are used to attempt to minimize damage. Fitted with detergent sprays and oil-skimming booms the tugs are sent to try to disperse or contain the spill before it reaches the coast.

Sea Containers Ltd

A Ro-Ro (Roll-on, Roll-off) *ferry being boarded by motorists at Dover docks – the busiest passenger port in the UK.*

The world's largest catamaran *(74 metres long) is designed to cut through waves of up to four metres rather than ride over them.*

destination faster than ever before. Fewer and fewer people will be needed to man ships and dockyard equipment. Already, large cargo ships can be run by just five or six people. A similar number can unload a container ship in a day or less. Eventually, there may be robot tankers and other cargo vessels, guided by orbiting satellites and navigation beacons on sea and land. Automatic berthing systems will allow these uncrewed ships to dock without human assistance and even be unloaded by computer controlled cranes.

Large modern ports, such as Rotterdam, New York, and London are being increasingly well linked with inland cities by road and rail services. This, together with more efficient loading and unloading of cargoes, means that freight can reach its

Robert Harding Picture Library

New York harbour *is one of the world's great natural harbours, its deep water being almost surrounded by land.*

Just amazing!

ON THE WATERFRONT

THE PORT OF NEW YORK AND NEW JERSEY, THE WORLD'S LARGEST, BOASTS 1,215 KM OF NAVIGABLE WATERFRONT AND CAN ACCOMMODATE 391 SHIPS AT ONE TIME.

Paul Raymonde